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THE COTTON MANUFACTURE

OF

GREAT BRITAIN

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THE

COTTON MANUFACTURE

OF

GREAT BRITAIN

SYSTEMATICALLY INVESTIGATED,

AND ILLUSTRATED BY 150 ORIGINAL FIGURES,

ENGRAVED ON WOOD AND STEEL;

WITH AN INTRODUCTORY VIEW OF ITS COMPARATIVE STATE
IN FOREIGN COUNTRIES,

DRAWN CHIEFLY FROM PERSONAL SURVEY.

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Vol. ii., p. 82, line 7, for "apex or summit," read "base or thick end."

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CONTENTS OF VOL. II.

BOOK III.

Chapter III.

Chapter IV.

THE

COTTON MANUFACTURE,

&c.

BOOK III.

CHAPTER III.

Description of the Preparation Processes of a Cotton Mill.

SECTION I.

Cleaning, Picking, Scutching, Blowing, and Lapping Machines.

WERE cotton wool delivered to the spinner in the same state as it exists in the pods of the plant, it would be found sufficiently open and clean to undergo immediately the carding operation; but, as we have shown in treating of the husbandry of cotton, the wool has to be compressed so strongly in bags, in order to facilitate its transport from the place of its growth to that of its manufacture, as to cause a matting together and entanglement of its filaments in tufts, which must be carefully undone before it is presented to the teeth of the cards, which would tear the matted filaments asunder, and ruin the staple.

The first operation of a cotton-mill therefore is to open up the cotton into its original spongy state, and at the same time to shake out any earthy or vegetable matters which may have been accidentally mixed with

it. As perfect uniformity is a prime quality in yarn, and as this will depend not a little upon the uniformity of the wool, this object is promoted by mixing together the contents of several bales of the same kind of cotton into one heap, commonly called a *bing*. The wool from every bag should be evenly spread in a stratum on a clean mat, so that, when several such strata are piled over each other, a section of them from top to bottom will afford an average of the whole stock. A tool like a hay-rake is sometimes employed to draw down and teaze asunder the agglomerated mass of cotton as it is wanted for the picking and other cleaning processes. Much skill may be shown in the suitable intermixture of different kinds of cotton, in order to improve a weak-stapled quality, and make it work into good yarn. Soft, short, riband-like filaments are best adapted for spinning into wefts; firm, long, and cylindrical ones are best adapted for making the wiry warps and lace-thread yarns. Cottons which differ much in the length of their staple and form of their fibres do not draw, rove, or spin well together. To make this choice with final precision, the tact of the fingers should be aided by the power of the microscope. Coarse wefts are made from Surats, Bengals, and the inferior Uplands, with waste tops from the blowing machine; but the better wefts for muslins require the finer staples of Bahia, Demerara, New Orleans, and the inferior Sea-islands. Warps are spun from New Orleans, Egyptian, Maranham, Pernambuco, and Sea-island, &c. The mixture of cottons of different qualities is very conveniently done by an apparatus attached to the lapping machine, as will be explained in its place.

Fine cotton, such as the best Sea-island, is generally cleaned and opened at first by the hand-labour of women and children. For this purpose it is spread in small quantities at a time on an elastic table of tesselated cords, called a *flake*, through the meshes of which the seeds and dust are made to fall, by beating it with slender rods or wands, while the spring of the table helps to open out the knots. Such impurities as resist this separating process are removed by the fingers.

Various machines for accomplishing the same object have been contrived. One of the earliest and most ingenious was that of Bowden, in which a parallel series of rods was made to strike upon a flake-table of cords, in imitation of beating by a number of hands. It was patented in 1801; but, being somewhat complicated and violent in its action, it did not keep its ground in the factories, though it was a powerful automaton. Each rod, after inflicting a flat blow, was drawn horizontally backwards by a sliding motion, and then raised vertically to discharge another blow by the power of a spring suddenly disengaged.

The *Willow* is the first machine in general use at present for opening out the entangled flocks of cotton wool. Its object is to clean the cotton slightly, by a sort of winnowing action, which led me to suppose that the name of the machine had been originally *winnow*. But M. Bourcart, an eminent cotton manufacturer at Guebwiller, in Alsace, informed me, that a cylindrical cage, made of *willows*, with a rotatory axis and cross arms, had been employed of old in Normandy for cleaning cotton, and probably sheep's wool, under the name of *le panier de Normandie*.

This simple mechanism, as obligingly sketched for me by him, is represented in fig. 22. It is undoubtedly the original of the English *willow*, both in form and denomination. The cotton is put in at the hopper, A, near the upper end, and on turning round the axis by a handle, or the pulley, B, by a band, it tumbles down the inclined plane, and falls out at the bottom, C, discharging through the interstices of the willow wands the earthy impurities in its progress.

Fig. 22.—The primitive Willow of Normandy.

The willow, as now used in the English cotton factories, is shown in figs. 23, and 24. Fig. 23 represents the front view, or working face; fig. 24 shows the cross section. The machine consists of a rectangular frame, A, fig. 24, revolving in the direction of the arrow, upon

its axis, B, which turns in bearings fixed to the frame, C, C, fig. 23. Upon the shaft or axis, exterior to the frame, are two pulleys, D, D, the first fast and the second loose—the former of which is called the steam-pulley in the factories, being that which puts the machine in gear or connexion with the steam power. This pulley derives motion from a strap in communication with the general shafting of the mill, as has been explained in the preceding chapter. Upon the four edges of the square revolving frame, A, are fixed a series of iron pins or pegs, which in the rotation pass

Fig. 23.—Square-framed Willow. Front View.
Scale, three-fourths of an inch to the foot.

between other similar pins, fixed to the inner surface of them antle, or case, E, of the willow. The inner

face is not concentric with the motion of the pins round the axis; but the fixed pins project on the inside to different distances, relatively to the centre, in order to effect the progressive opening out of the cotton by the successive teazing motion of the rows of pins, *a*, *b*, *c*, of progressively increasing lengths.

The bottom of the willow is formed of a semi-cylindrical wire grid, F, F′ (cage-like), one half of which,

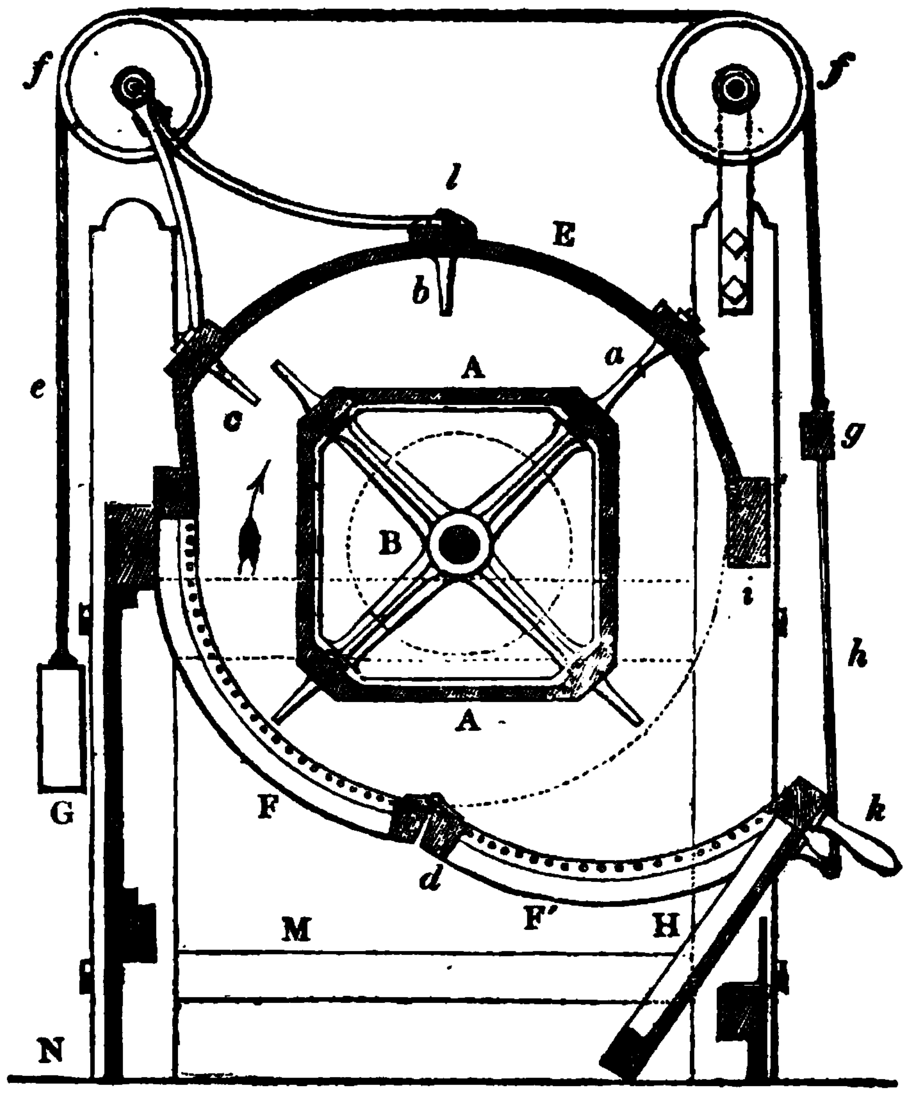


Fig. 24.—Square-framed Willow. Side View.
Scale three-fourths of an inch to the foot.

F, is fixed, and the other, F′, is movable round the hinge at *d*. This movable part is counterpoised by a weight, G, from which a rope, *e*, proceeds, passing over the pulleys, *f*, *f*, and is fixed to a bar of wood, *g*, *g*, fig. 23, to whose ends are attached the two

slender rods, *h*, *h*, which suspend the movable part of the grid. To this part a door, H, fig. 23, is connected, which serves to shut the front opening of the willow-case when the grid, F′, is raised by the hand of the workman to the level of the dotted line, *i*. The handle, *k*, is used for lifting the door, and for fixing it in a closed state by means of the hook, *m*, fig. 23, attached to the frame.

In working this instrument, the boy who tends it lets down the door, throws in an armful of cotton upon the folded-down face of the grid, F′, and instantly shuts the door, which brings up the grid into the circle of the willow, *d*, *i*. The revolving frame, A, now agitates the cotton between its own pins and those of the case, whereby it is opened up, and discharges its dust through the grid, F, F′, into the subjacent space, M, which is cleared out from time to time through a door, N, in the back part of the willow. In some factories this chamber is put in communication with a fan, which serves to suck out the lighter dust as it is separated from the cotton wool. After the cotton has been wafted about for a few seconds, the tenter-boy lets down the door, H, and dexterously lifts the cotton from the folded-down grid, F′, where the machine always throws it. He then introduces a fresh quantity.

The proper speed of the steam-pulley axis, and of course of the revolving frame, A, is considered to be 600 revolutions per minute. A machine armed with such strong iron pins, and turning with such velocity, has a dangerous aspect, and must undoubtedly be managed with discretion. I inquired particularly concerning the chance or frequency of accidents with the

willow, in my tour through the factory districts, and found that they were very rare. I saw that the cotton was all deposited upon the depressed grid, F′, quite out of the limits of the revolving spikes. In fig. 23, the series of iron nuts, *l, l, l,* corresponds to the series of iron pins, *a, b, c,* in fig. 24, which project from the inner surface of the case.

A skilful spinner of Stayley Bridge assured me that spiked willows should be used in all cases with extreme tenderness and circumspection, especially on long-stapled cotton wool, as they were apt to draw it into knots; for the inferior, foul cotton wools—such as the Surats, Bengals, and some of the Upland Georgia, the following machine, the Conical Willow, as made by Mr. Lillie, is of remarkable power. It cleans and opens from 12,000 to 15,000 pounds of cotton, without injuring the staple, every week at Messrs. Marshall's factory, at Portwood, Stockport; in another establishment it winnowed the surprising quantity of twenty-four bags, equal to 7,200 pounds, in one day, for coarse spinning.

New Conical Self-acting Willow.

To obviate the danger and interruptions of work to which the preceding machine is liable, the following modification, borrowed in some respects from the wool willow, has been lately introduced into the cotton factories. Here the cotton wool is continually fed in at the one end, and given out at the other, without any manual intervention, strictly speaking—an effect due to the centrifugal motion imparted to the filamentous flocks by the rapid revolution of a cone within a concentric case, furnished with iron pins or spikes, as in

the square-framed willow. The cotton is drawn in at the smaller end or summit of the cone, and is whisked onwards to the larger end or the base, where it falls

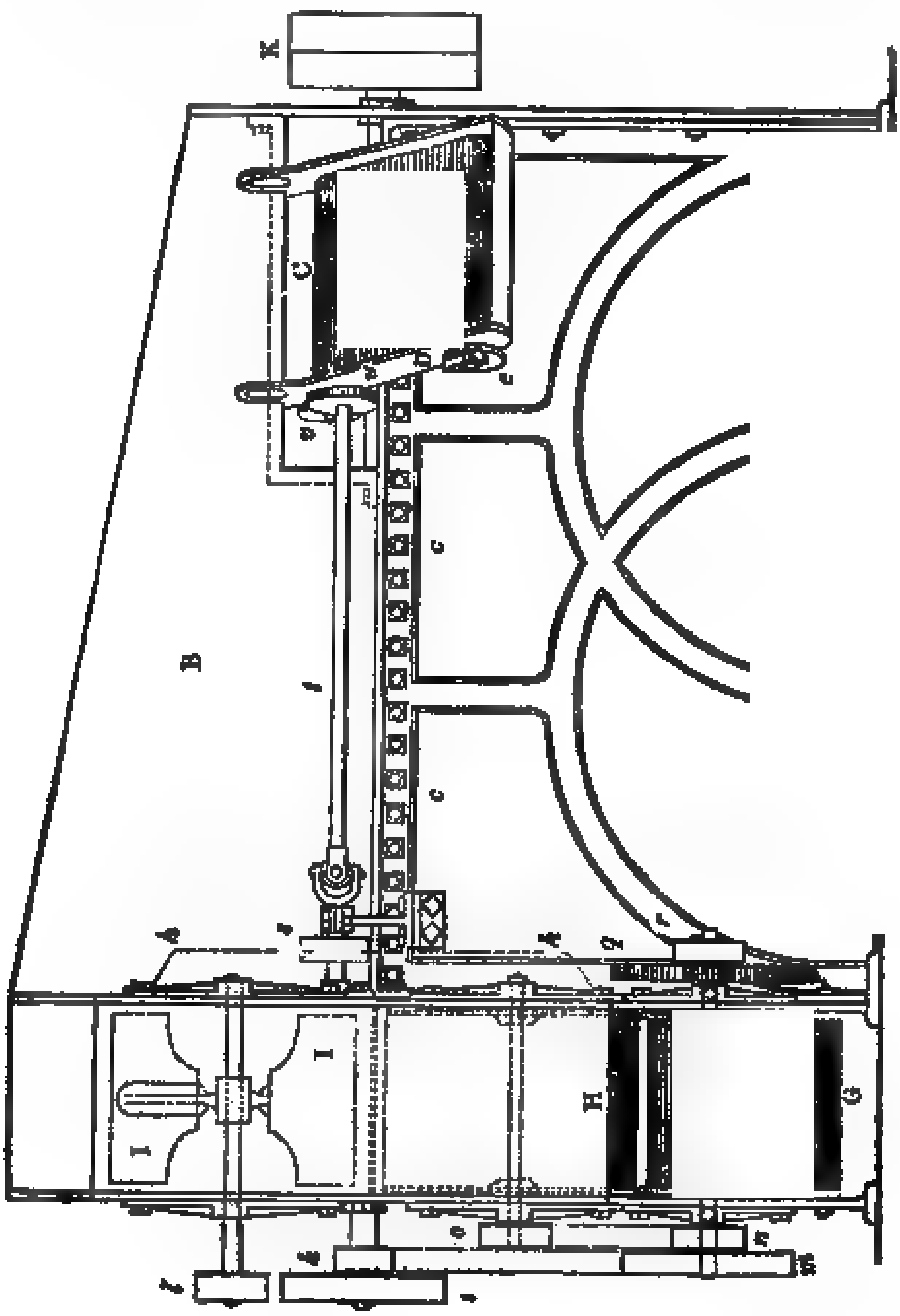


Fig. 23.—Conical Self-acting Willow. Longitudinal View. Scale, half an inch to the foot.

upon a moving apron, or delivering-cloth, which turns it gently out upon the floor of the apartment.

Fig. 26 is a longitudinal view of that side of the conical willow which receives and discharges the

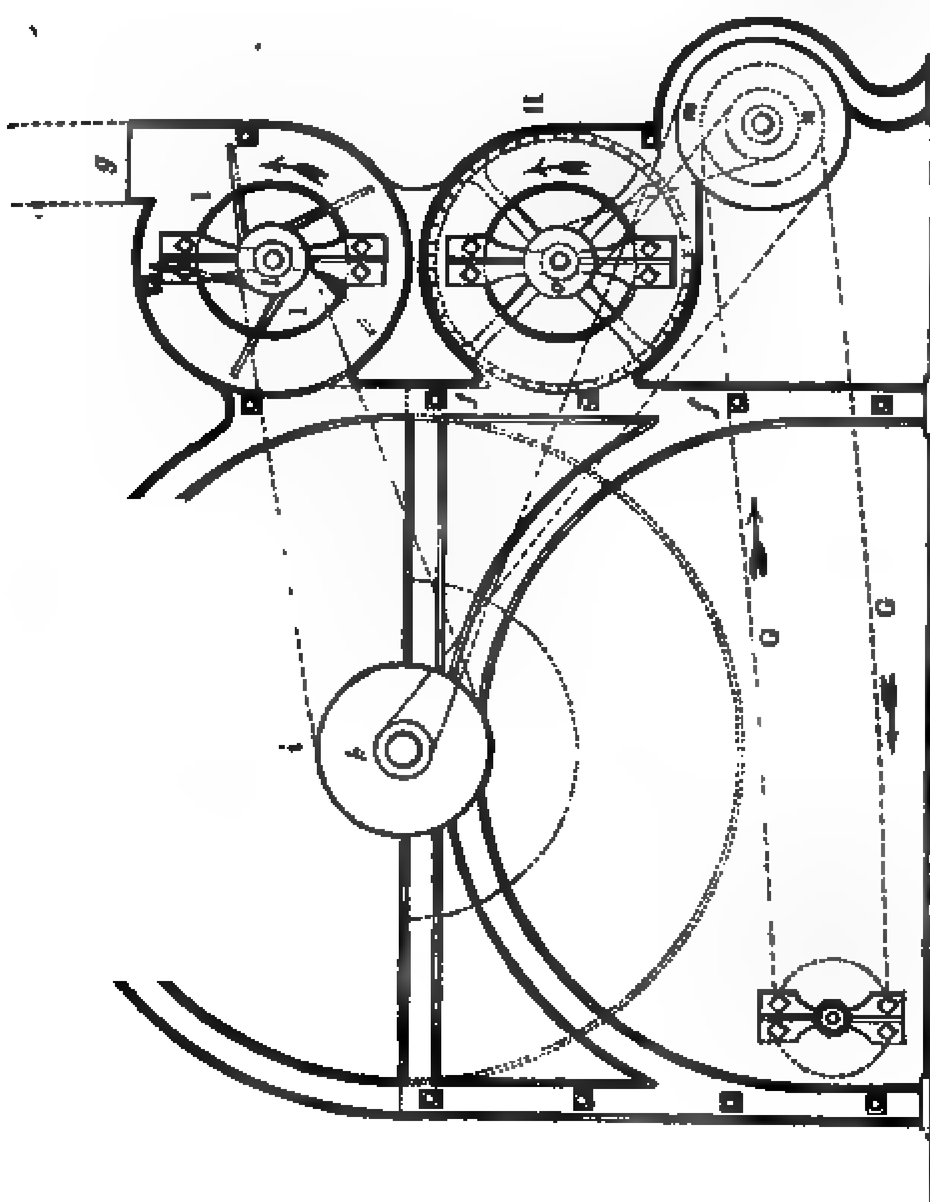


Fig. 26.—Conical Self-acting Willow. End View.
Scale, half an inch to the foot.

cotton; fig. 26 is an end view; fig. 27 is a top view, with part of the casing and frame-work removed to

show the interior structure; fig. 28 shows a part of the perforated iron plate, or grid, which forms the

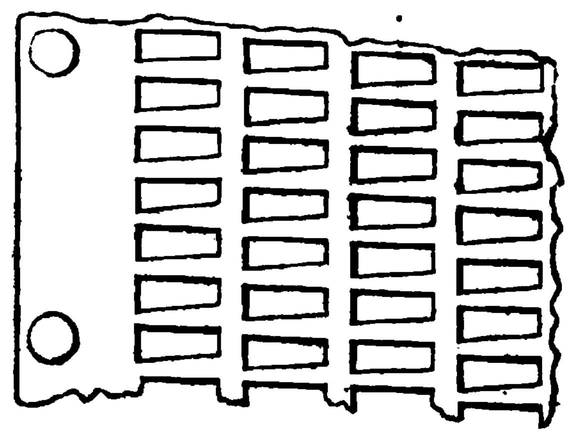


Fig. 28.—Bottom Grid of Conical Willow.

bottom casing round the cone. A parallel wire-grating, such as exists in the common willow, has been also employed. The cone, A, consists of a strong shaft, *a, a,* mounted with three cast-iron rings—one being at each end, and one in the middle—for the purpose of supporting the sheet-iron mantle which forms the surface of the cone. Along this surface, four equidistant iron bars are riveted parallel to the axis, into which four lines of strong iron pins or pegs, *b, b,* are screwed by means of nuts. Corresponding to the intervals of these pins, one line of pins, *d, d,* is fixed by other nuts, *c, c,* fig. 25, upon each side of the easing-frame interiorly. The top of the cone is covered with a concentric case, B, fig. 25, while the bottom casing consists of the grid, or screening-plate. In the top casing, near the narrow end, there is an oblong aperture, C, to which a frame, D, is attached, that carries an endless apron, E. Upon this apron-frame the cotton flocks from the bing are spread by hand. The apron consists of parallel slips of thin sheet iron, three-quarters of an inch broad, placed at intervals of half an inch asunder, riveted at their ends

Fig. 27.—Conical Willow. Top View.
Scale, half an inch to the foot.

to two endless leather straps, which travel upon pulleys fixed to two shafts parallel to the sheet-iron slips, one of which shafts is moved by wheel-work, and the other is adjustable by set screws, which act upon the bearings of the shaft, so as to tighten the strap at pleasure.

At the wider end of the machine there is a chamber, F, fig. 26, into which the cotton is whisked out of the cone, after having been whirled onwards from its narrow end, and is received upon a moving apron, like the former, which is seen at fig. 27, and at the dotted lines, G, G, fig. 26. About an inch above the surface of this apron, a cylindrical wire cage, H, revolves upon an axis parallel to the apron. This cage is shown at fig. 27, and by dotted lines in fig. 25 and 26. It is enclosed in a case of sheet-iron, which communicates at its side, *f*, *f*, fig. 26, with the chamber, F. Over this cage, between the frame-work of the machine, a fan, I, enclosed in a similar case, is placed, which sucks out the dust of the cotton wool through the wire cage from the chamber, F, beneath it, and blows it out through a large pipe in connexion with the orifice, *g*, fig. 26. This cage not only prevents the cotton fibres from being wafted away with the dust, but lays them down by its rotation upon the travelling apron.

The wire cage and the fan are placed in communication by a flat tin-plate cover, or lid, which embraces at once both the orifices at the ends of the two axes of these cylinders, and is shown by interrupted lines at *h*, fig. 25. The other ends of the fan and cage, seen in fig. 26, are left open, in order to draw out the dust, and to ventilate the air of the apartment.

The motions of this elegant automatic machine are given as follows: Upon the shaft, *a*, of the cone, A fig. 27, the usual fast and loose pulleys, K, K′, are fixed, by which the cone may be put in or out of gear at pleasure. Upon the other end of the same shaft two other pulleys, *i* and *k*, are fixed, the first of which gives motion to the fan, I, by a strap moving the little pulley, *l*; the second pulley, *k*, gives motion to the apron, G, G, by driving the pulley, *m*, made fast to one shaft of the apron. Upon the same shaft there is a smaller pulley, *n*, which, by means of a strap and pulley, *o*, drives the wire cage, H. At the other end of the last shaft, there is a pinion, *p*, which drives the the wheel, *q*, and its attached pulley, *r*. From this pulley, *r*, a strap goes up to the pulley, *s*, which turns a shaft, *t*, furnished with a Hook's universal joint, for the purpose of converting the motion parallel to the axis of the cone, into a motion parallel to its side, as is clearly shown in fig. 27. This shaft, with the universal joint, is supported at its other end in the frame, D, and it carries a toothed wheel, *u*, which drives the wheel, *v*, upon the apron-shaft; and thus the feeding apparatus is moved.

The velocity of the cone may be from 400 to 600 revolutions per minute.

The mode of action of this willow is obvious, from the preceding detail of its structure. The cotton slowly introduced by the creeping-apron, E, is teazed out by the spikes of the cone revolving in the direction of the arrow, fig. 26, and thus is made to discharge its heavier impurities, twigs and stones, through the grid-work bottom. On advancing to the other end by the centrifugal force, its lighter dust is wafted out

by the fan through the squirrel-cage sieve, and blown away through square pipes into an adjoining closet. The filaments thus cleaned are discharged from the apron, *w*, fig. 27, in the direction of the arrow.

The above machine belongs to the class formerly called the Devil, or Wolf.

Batting, or Scutching, and Blowing Machines.

The next process to which cotton is subjected in a spinning factory, is that of batting (beating) and blowing, by a machine called sometimes by the one name and sometimes by the other. Its object is to loosen thoroughly the filaments of the cotton already partially cleaned by the hand or the willow, and to carry off, through fan-sieves, the remainder of the dust. The beating action is produced by flat bars carried rapidly round, which strike with their faces the cotton fibres as they are slowly introduced from the feeding rollers, connected with the feeding apron-cloth. In each machine there is usually a double set of the beating or scutching apparatus, from the last of which the cotton is frequently discharged upon the floor of the apartment, whence it is removed to the next machine, in order to be scutched again, and lapped into a cylindrical roll. But a much more improved, and far preferable plan, is that represented in Plate III, where the batting machine turns out the cotton in the form of a cylindrical lap, without the labour of gathering and spreading, and ready to be applied to the next machine, where the different sorts are occasionally mixed, before being finally made into a lap for the carding operation.

In many fine spinning-mills, where the best Sea-

island cotton is used, batting machines are dispensed with, and the hand-picked and beat cotton is at once evenly spread upon the feed-cloth of the cards. Plate III, and wood-cuts 29, 30, 31, represent a con-

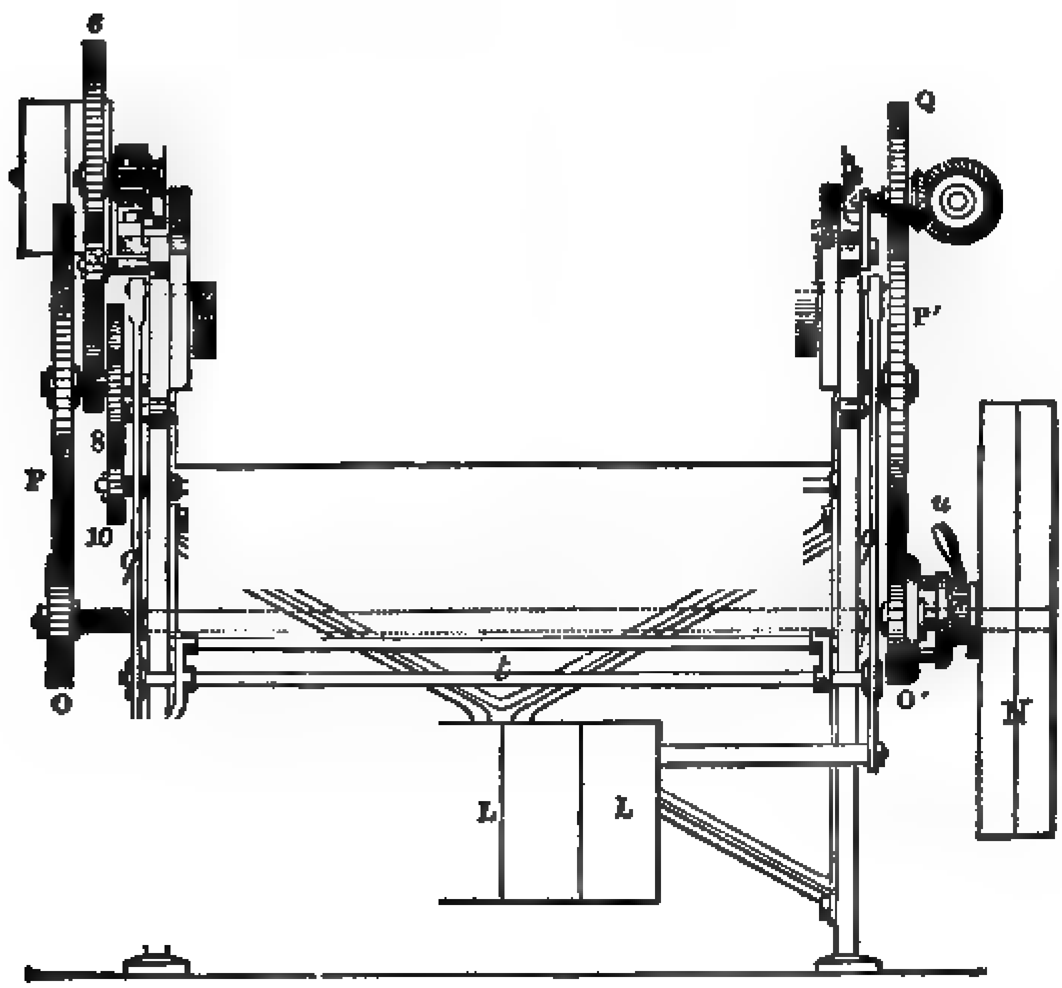


Fig. 30.—Front View of the Lap Machine.

nected system of apparatus, embracing the batting and the lapping machines. Plate III is a longitudinal section of a double batting or blowing machine, with the lap mechanism attached to it. The feed-apron is about eight feet long: part of it is shown at A, where

Fig. 27.—Longitudinal Section of th

the one end passes over a roller, *a*, as its further end does over the fellow roller, beyond the limits of our figure. Fig. 29 is a longitudinal section of the proper lap machine. Fig. 30 is a front view of the lapping mechanism, representing, in fact, the delivering end of both the preceding machines. Fig. 31 is a longitudinal view of the outside of the lapping apparatus, to show the working parts common to both engines. The same letters of reference denote the corresponding parts in the four figures.

The willowed cotton is spread by hand about two inches thick upon the apron-cloth, A, plate III., and is carried forward by it at the rate of about three feet per minute, to the feed-rollers, *b, b*, which are pressed together by a weight acting through the lever, *c*, upon the brass bearings of the top rollers. A wooden roller, *d*, serves to keep the cotton close to the apron, and to facilitate its introduction between the feed-rollers, which consist here, as in the carding-engines generally, of small iron cylinders coarsely fluted parallel to their axes. B is the first beater, consisting of two flat bars, *e, e*, fixed at right angles upon the arms of the revolving shaft, so as to strike upon the cotton filaments as they issue from between the feed-rollers. This, the scutching shaft, is made to revolve with a velocity of 2,000 turns per minute, by means of a strap proceeding from a pulley upon the mill shaft near the ceiling, as has been explained in Chap. I., Book III. C is the harp, a grating or grid, in the form of the quadrant of a cylinder, composed of long flat bars, against whose edges the cotton is scutched by the beaters, and thereby thoroughly opened, after which it is wafted upon the endless apron D. This apron

consists of thin spars of wood about three-quarters of an inch broad, and half an inch apart, fixed at their ends to two endless leather straps, which turn round the rollers, *f* and *g*, the latter being driven by the outside wheel-work.

Near the end of the apron there is a revolving cage-cylinder, E, enclosed under the general cover, *h, h, h*, through the top of which there is a pipe, *i*, in communication with a rotatory fan, placed in any convenient part of the room. This cylindric cage permits the dust to be sucked through it, and also serves to spread smoothly upon the apron the loose cotton filaments into a level fleece, which passes off under the wooden roller *h*, and is thence drawn in by the second pair of feed-rollers, *l, l*, in order to be exposed to a second scutching by the beater-bars at F, the axis of which revolves 2,200 times per minute. This increased velocity does no harm to the flocks of cotton in their loosened state. The second beater delivers the filaments upon a second apron, G, similar to the first. Here it is exposed to the sucking action of a second sieve-cylinder, in communication by the orifice, *m*, with the general fan ventilator.

The cotton, once more formed into a fleecy nap, is brought out by the rotation of the roller, *n*, and now, instead of being thrown upon the floor, as formerly, it is carried through between the two pairs of iron rollers, *o′, o′* and *p, p*, the upper ones being weighted (loaded) as shown in the engraving. These rollers deliver the compressed fleece to the wooden lap-cylinder I, whose axis is loaded with weights, L, L, L, so as to bear down between the two rollers, K, K, which, revolving both in one direction, as shown by the arrow,

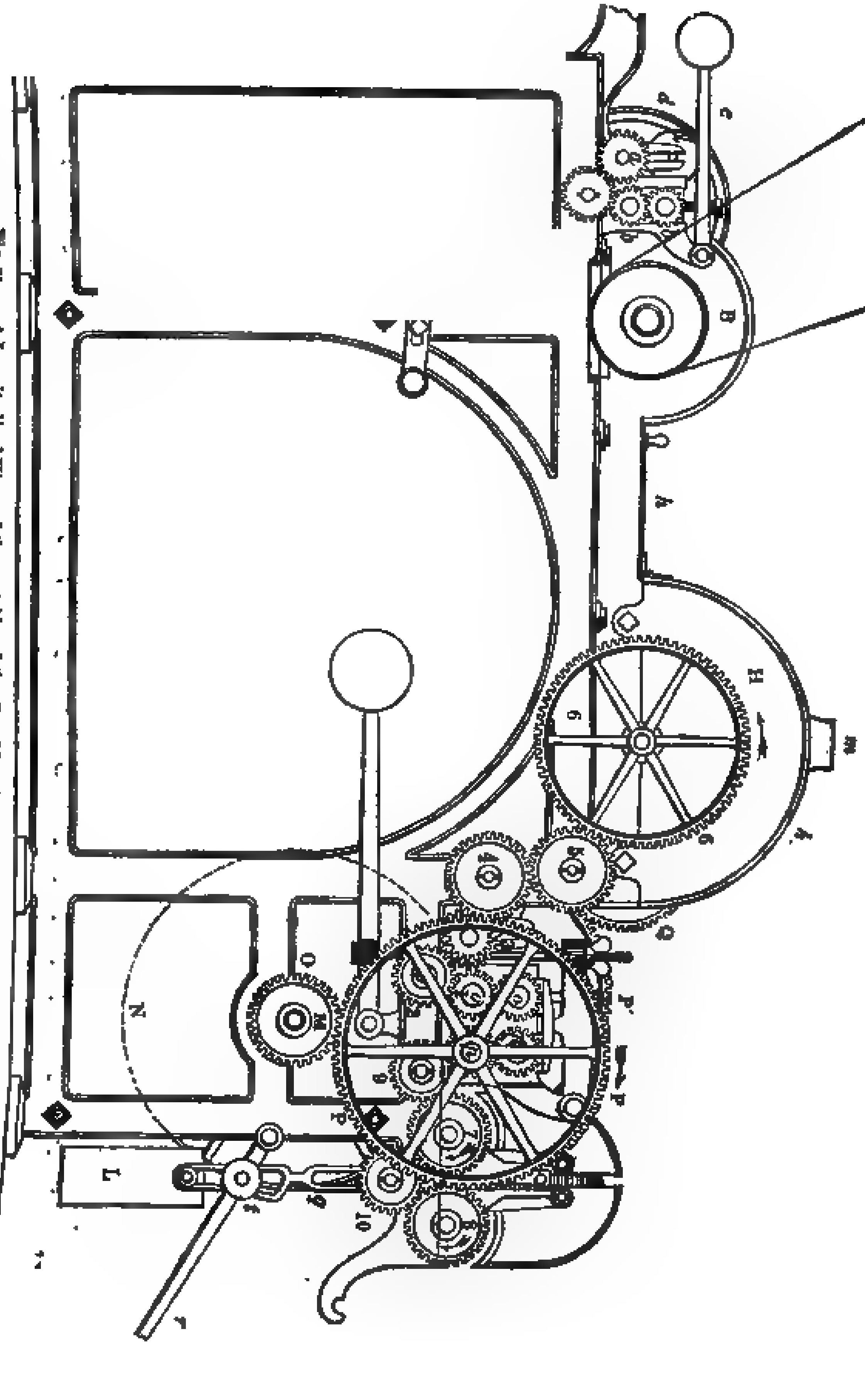


Fig. 31.—A Longitudinal View of the outside of the Lap Machine to show the moving mechanism.

carry round with them by friction alone the lap-cylinder. As this cylinder increases in diameter, the links, *q*, *q*, progressively rise up with their weights, L, L, so that the pressure continues always uniform. Whenever the coil of lap has acquired the proper size, the twin rollers, *o′*, *o′*, with the aprons, cages, and feed rollers, throw themselves out of gear, whilst the twin rollers, *p*, *p*, and the lap-cylinders continue to revolve, whereby the fleece is torn or cut across in the middle line between the two pairs of twin rollers. The attendant now lifts the lever, *r*, which raises the links, *g*, *g*, and suspends the weights, L, L, by the hook, *s*. Thus he relieves the axis of the lap-cylinder, removes it, and puts an empty one in its place. He now throws the machinery once more into gear, disengages the connecting rod, *t*, from the suspending hook, *s*, and restores the action of the weight, at the same time that he guides the beginning of the fleece round the empty roller, *see* fig. 30.

The beaters, B and F, derive their motions from the mill shaft, independently of the rest of the machine, by means of pulleys shown by dotted lines in the engraving. Near the finishing or discharge end of the blower, there is a cross shaft, M, upon whose end there is a pulley, N, which revolves 36 times in the minute. Upon each end of the same shaft there is also a toothed pinion, O, O′, which drives the wheels, P and P′; the first of them being made fast to the end of the under roller, *p*, and the second to the end of the next roller, *o′*. By disengaging the pinion, by means of the lever, *u*, fig. 30, from the shaft, M, the wheel, P, will be set at rest, as well as the other parts driven by this wheel.

It is obvious, therefore, that by this arrangement

the fleece may be cut across between the rollers, *o, o*, and *p, p*, as formerly stated; in consequence of the first pair of rollers being stopped, while the second pair continues moving.

A wheel, Q, as shown particularly in fig. 31, and by dotted lines in plate 3, transmits motion to the feed-rollers, *l, l*, and *b, b*, to the cylindrical cage, E, and to the apron, D, from the wheel, P, by means of bevel wheels and a horizontal shaft, as shown by dotted lines in plate 3. Upon the other end of the roller, *o*, is a wheel that gives motion to the apron, G, and to the cage, H, as is shown in fig. 31, where the carrier wheel 2 drives the wheel 3 of the apron roller, *n*. Upon the axis of wheel 3 is a pinion which drives the carrier wheels 4 and 5, and thereby the wheel 6 upon the shaft of the cylindric cage, H. The roller, *p*, driven by the large wheel, P, has upon the same end of the axis a pinion which drives the rollers, K, K, of the lapping apparatus, by means of wheels 7 and 8, and the carrier wheels 9 and 10, as shown in fig. 31.

The preceding explanation applies fully to the lap-machine, as represented in figs. 29, 30, 31; the only difference being in the mode of feeding, which, in fig. 29, consists in an endless apron moving between a frame, upon which there are slot bearings, R, for receiving the ends of the wooden pin that is thrust through the central hole of the lap, after the withdrawal of its roller. Upon this frame as many pairs of slot bearings are affixed as there are different sorts or laps of cotton to be mixed.

By the movement of the apron the fleece is unwound from each lap, and carried forwards in parallel layers, lying over each other, by the traction of the feed-

rollers. In the excellent machine, of which the preceding figures are a faithful delineation and analysis, there were five slot bearings, two of which carried laps of New Orleans cotton wool, and three, laps of Bahia. Many of the mechanical contrivances above described are new, and the whole execution and performance of the engines are highly creditable to their constructor, Mr. Crighton, of Manchester. The beaters of such machines make from 1,800 to 2,200 revolutions per minute.

The scutching machine was originally invented by Mr. Snodgrass, of Johnston, in Renfrewshire, and afterwards improved by Mr. Peter Cooper, of the same place. The lap-apparatus is sometimes called a spreading machine.

Different staples of cotton require different degrees of scutching; the short and soft staples admitting of less powerful and rapid beating than the firm and long staples. For the last, the beating-bars should be adjusted at a greater distance from the feed-rollers, to prevent the filaments from being torn. For accurate work, the cotton wool should be laid upon the feed-cloth in weighed quantities, and very evenly spread or distributed.

These mechanisms require to be frequently cleaned, and to be lubricated at the moving parts, both on account of their extreme velocity, and of the dusty and downy particles, which are apt to clog the axes and bushes by inspissating the oil. When in good order, they will put through 5,000 pounds of cotton wool in a week of 69 hours, and supply 21 cards (breakers and finishers), with a sufficient lap, in a mill spinning from 35'*s*. to 40'*s*. The great speed of the beaters produces a current of air which carries the filaments onwards

in the machine; but to remove the dust entirely an independent ventilator is employed, as already stated, which, like the scutching and spreading engine, takes about a horse power to drive it at a proper speed.

We shall introduce here the description of the ventilator employed in modern mills, as constructed by Messrs. Fairbairn and Lillie.

Figs. 32 and 33 represent a side and front view of

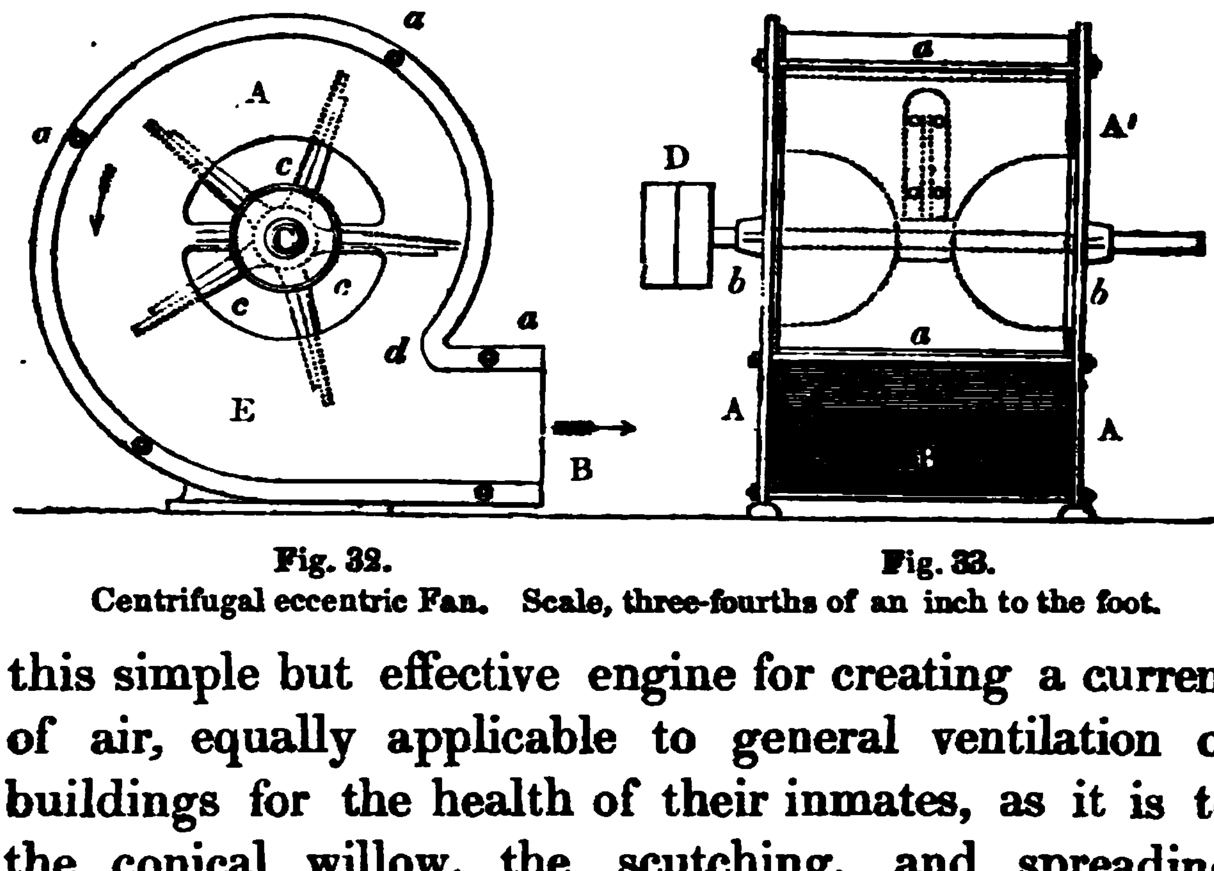


Fig. 32. Fig. 33.
Centrifugal eccentric Fan. Scale, three-fourths of an inch to the foot.

this simple but effective engine for creating a current of air, equally applicable to general ventilation of buildings for the health of their inmates, as it is to the conical willow, the scutching, and spreading machines. It consists of two cast-iron end plates, A, A′, provided with a central circular opening, *c, c, c,* from whose circumference the outer edge of each plate enlarges in a spiral line; the point of it nearest the centre being at *d,* and the one farthest from the centre being at the base under E, fig. 32. This pair of parallel plates is connected by bolts *a, a, a,* a mantle or case of sheet-iron having been previously fitted into grooves cast in the edges of the said plates. By this means a cavity or chest is formed, which has an

elongated aperture at B, to which a pipe may be attached for conducting the discharged air in any direction. Within this cavity a shaft, C, is made to revolve in bearings, *b*, *b*, placed centrally in the plates, A, A, and cast in the same piece. Upon the shaft a boss is made fast by wedges, which carries five flat arms, seen in section fig. 32, at the sides of *c*, *c*, *c*, to which five flat plates are riveted. These vanes or wings have each the form represented in the front view between *a*, *a*, being rectangular plates of iron, with a semi-circular segment cut out of their edge upon each side, whose diameter is equal to that of the end opening in the case. Upon one end of the shaft, C, exterior to the bearing, *b*, the fast and loose pulleys are fitted for receiving the driving strap, and for turning the vanes in the direction indicated by the arrow in the side view, whereby the air is expelled before them out of the end orifice at B, while it is allowed to enter freely by the side openings at *c*, *c*, *c*. By the centrifugal force of these revolving vanes, the air is condensed towards their extremities, makes its escape from the pressure through B, and is continually forced in at the sides, in virtue of the atmospheric equilibration.

Some ventilators have their hoods or mantles made concentric with the revolving vanes, and though they do good work when turned with great velocity, they are not well adapted to produce pressure by condensation of the air; for the wind at the outlet B consists partly of the air compressed by the extremities of the wings, and of the air rarefied on its entrance near their roots. In the fan here represented, called the eccentric, the air which is driven out from B, has been

subjected to compression during its whole course through the spiral space before the revolving wings, and is equal in density to that compressed at their extremities by the centrifugal force. This engine discharges therefore a considerably greater body of air than the fan with a concentric mantle, because each wing, in passing the point *d*, acts as a valve to intercept the ingress of the uncondensed quiescent air, which would cause an eddy, and retard the rapid current by the inertia of its particles. The wings are usually made to revolve with such speed as to pass through a space of from 80 to 100 feet in a second.

When the fan is employed to draw air out of the willow, the batting machine, or chambers of any kind, the circular openings in its sides must be enclosed within caps, which are then connected with pipes placed in communication with the cavities or spaces to be acted upon. Slide valves or throstle-valves may be introduced into these exhausting pipes, or into the condensing pipe connected with B, in order to modify the rarefying or blowing force. The last arrangement is adopted with signal advantage for applying a regulated blast to forge fires.

I have found experimentally that a fan like the above, 18 inches in diameter, and 12 inches in width, moving its wings at the rate of 120 feet in the second, supports by aspiration, in a syphon, a column of water two inches high, and when it moves at the rate of 180 feet, it supports a column three inches. The chimney of an excellent drawing air-furnace does not support, by aspiration, more than one-seventh of an inch.

SECTION II.

Carding Engines, or Cards.

The objects of the carding operation are to separate the fibres which, in their imported state, are entangled in small tufts and knots, and which have been but imperfectly opened in the blowing machine, so as to draw them out into somewhat parallel directions, and to remove completely all the residuary impurities. The carding principle consists in the reciprocal action of two surfaces, which are mounted with hook-shaped elastic wire points. These little hooks, made of hard-drawn iron wire, are represented in fig. 34. The wire

Figure 34.

Fig. 1. Fig. 2.

must be first bent at right angles, as at *a* and *b*, fig. 1; then each branch must receive a second bend, as at *c* and *d*, fig. 2, at a determinate obtuse angle, which must be invariable for the same set of cards. It is indispensable that these two obtuse angles, *a, c, e, b, d, f,* be mathematically equal, not only for the two conjoined points, but for the whole series of teeth; for if one of them slope more or less than its fellow, it will lay hold of more or less cotton wool, and cause the carding to be irregular.

The leather must be pierced by a fork, with two holes for each double tooth, at the distance *a, b,* but in such a way that the inclination of these holes, in reference to the plane surface of the leather, be in-

variably the same; otherwise the length of the teeth would vary with the angle of inclination, and spoil the card. Another condition in making good card cloth, or *garniture*, is to have the leather of uniform thickness. This is effected by a species of planing machine, which strips the surface smooth, and renders the thickness equable. A riband or sheet of leather thus furnished, being made fast to either a flat or cylindrical surface of wood, will constitute a flat, or a cylinder card. Suppose *a*, fig. 35,

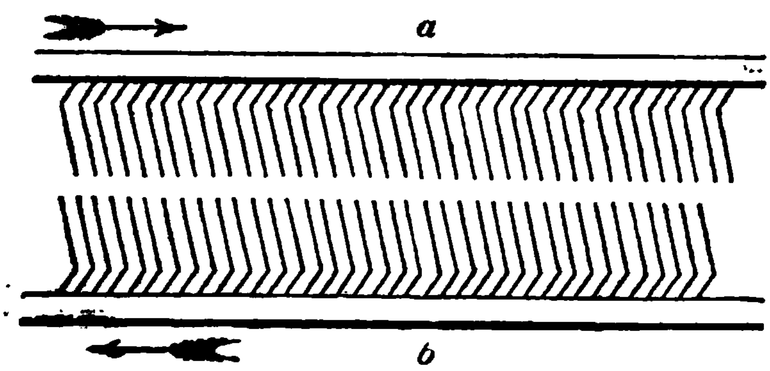


Fig. 35.—Card Teeth.

to be one such card, and *b* to be another, whose teeth are set in opposite directions, the two wire surfaces being parallel, and very near each other, with a tuft of cotton wool betwixt them. Let *a* be now moved in the direction of the arrow, the points of the opposite sets of teeth being in contact, while *b* remains stationary, or is moved in the opposite direction; it is obvious that every small flock of the wool, placed in such a predicament, must experience the traction of both sets of teeth. The teeth of *a* will endeavour to pull the filaments away with them, while those of *b* will keep hold of them, or pull them in the contrary direction. Each of the teeth will, in fact, appropriate to itself a portion of these filaments, and will thereby disentangle the tuft of cotton, thus drawing out the fibres, and placing them lengthwise, agreeably to the

line of traction. If this operation be often enough repeated, it must eventually arrange all the filaments in a direction truly parallel, and thus accomplish the end in view. Suppose, now, the whole filaments to be hooked upon the card *a*, a single cross stroke of the two will transfer to *b* a portion of those upon *a*, should the teeth of *b* be moved in the same direction with those of *a*, but more slowly. If the cards be so placed that the sloping points of their teeth look the same way, as in fig. 36,—and if *a* be moved in the

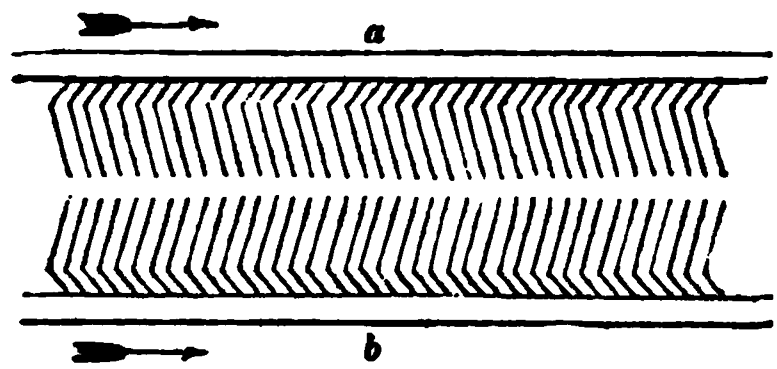


Fig. 36—Card Teeth.

direction of the arrow, while *b* is stationary, or is moved more slowly in the same direction,—*a* will comb all the wool out of the teeth of *b*, since the hooks have in this position no tendency to retain the filaments. The consideration of these different results, according to the different circumstances now stated, will enable any one to comprehend clearly the action of the carding engine.

For carding long-stapled fine cotton, one operation is not sufficient to clean the fibres completely, and to lay them in parallel positions, ready for the next process of a spinning-mill. Two cardings are had recourse to in this case; the first, by what is called the breaker cards, and the second by the finisher cards. The two operations do not, however, essentially differ from each other.

The cylinder cards, invented by Lewis Paul, and patented in 1748, were covered parallelly to the axis with fillets of leather thus mounted, having intervening stripes free from points. A concave card of the same curvature as the cylinder was applied to its under surface. Hence, on turning the cylinder by the handle at its end, the two bristling surfaces worked against each other, and performed the carding operation. When the filaments were thought to be sufficiently carded, the stationary concave part was let down, and the cylinder was then stripped of its wool by means of a comb made of a bar of wood, bearing a row of needles. These card-ends of the length of the cylinder were joined together by a particular contrivance which it is unnecessary now to describe.

When the concern of Lewis Paul, at Northampton, came to be dismantled by the failure of his operations, the carding cylinders were purchased by a hat manufacturer from Leominster, and applied by him to the carding of sheeps' wool for hats; and about the year 1760 they were introduced into Lancashire, and re-applied to the carding of cotton, by a gentleman of the name of Morris, in the neighbourhood of Wigan.*

Mr. Peel was one of the first Lancashire manufacturers who adopted this mode of carding, being assisted in carrying it into operation by James Hargreaves, the ingenious author of the Jenny. His machine was composed of two or three cylinders, covered with the card-fillets; and the carded cotton was taken from the cylinders by hand-cards applied by women. This process answered so indifferently, that Mr. Peel laid it

* John Kennedy, Esq., in Memoirs of Manchester Society, vol. v., second series.

aside. Then Arkwright took the cylinder-card in hand, and made it a practicable machine, about the year 1770, or 1771.* The feed-apron, as applied to cylinder-carding, has been claimed as an invention of John Lees, a quaker, of Manchester, in 1772; but there is no doubt that Arkwright had previously used the same contrivance, along with the crank and comb, at Cromford; for continuity in the discharging riband, at one side of the cards, obviously implies continuity in the feeding fleece, at the other side. In fact, the crank and comb, with its incessant stripping action, would have been a preposterous apparatus, without a corresponding punctuality of supply. Arkwright, indeed, refined upon the feed-apron, by rolling it up into a coil, after having spread the cotton evenly along it in an extended state, and thus fed the cards by the gradual unrolling of the apron-cloth. There can be no reasonable doubt in the mind of any man, acquainted, however slightly, with the carding process, that Arkwright had also used doffer cylinders, covered all over with spiral fillets, along with the crank and comb, in 1771 or 1772; for had his doffer been covered with pieces of card-cloth parallel to its axis, like the card-drum, with intervening bare spaces, the machine could not have turned off continuous ribands, as it did. It is preposterous to ascribe to Wood and Pilkington, about the year 1774, what Arkwright must have done two or three years before, though he did not specify it in a patent till 1775, on bringing his whole system to maturity. Then, indeed, all the schemers

* I was informed by Mr. Strutt, that Mr. Arkwright says he remembers of his father, Sir Richard, getting cylinder-cards from Northampton.

who had perchance imagined something similar to some of its parts, though never able to make them operate productively, began to put in their claims, and they were well encouraged by the many sordid and invidious rivals of the Cromford Company. In fact, it was impossible for Arkwright to keep any invention secret in his mill, when almost every one of his workmen was bribed to act as a spy, and report the progress of his improvements.

Carding-engines may be defined to be brushes of bent iron wire fixed in leather, and thereby applied to a set of cylindrical and a set of plane surfaces, the former being made to revolve so as to sweep over the surfaces of the latter at rest. Sometimes large cylindrical cards work against the surfaces of smaller cylindrical cards, moving at a less velocity; and occasionally both plans are combined in the same engine, as the following figures will show. The tufts are held fast by the stationary or slow-moving cards, while the quick-moving cards teaze out the fibres, and gradually disentangle them. Hence we can understand how fixed cards, in which the tufts are exposed to an uninterrupted course of teazing, disentangle the long-stapled cotton better than the squirrel or secondary revolving cards, which bring the tufts under the action of the great drum-card only once in each one of their revolutions. They exercise a greater tearing force, and are therefore used for coarser and shorter stapled cottons, with which rapidity of work is an object of importance. In fact, much more cotton can be passed through in the same time when both the main card and the counter cards revolve; and as the latter require less frequent cleaning than what are called the flat-top cards, this system is generally used in prepa-

ration for the lower counts of spinning; and occasionally in combination with fixed tops in that of the middling fine yarns.

Figs. 37, 38, 39, represent a carding-engine, in which both systems are combined, and constructed upon the best principles. Fig. 37 is a longitudinal section, fig. 38 the front view, where the carded cotton is seen to be delivered, and fig. 39 is a longitudinal view of the side of the engine, where the principal wheel-work lies.

In fig. 37, A is the main carding cylinder, constructed of parallel segments of mahogany, *a, a,* screwed upon three or four cast-iron rings fixed to the central shaft. Upon each of these segments a card-leather (card-cloth) is nailed in a length equal to the width of the main cylinder or drum. The inclination of the card-teeth is visible in the figure. B, B, *f,* are parallel segments of mahogany, called card-tops, which rest with their ends upon heads of screws, *b, b,* fig. 39, projecting from the side-framing, *c,* of the engine, and they are held in their places upon the frame by pins, which pass through their ends. The interior curvature of these segments is covered with a narrow fillet of card-leather. This surface may be placed nearer to, or farther from, the card-drum, A, by adjusting the screw-props at the end of each segment. This structure is clearly seen at *b, b,* in fig. 39. D, E, F, G are rollers covered with card fillets wound spirally round them from one end to the other. These small cylinders, called urchins or squirrels, revolve by their necks in the bearings, *d, e, f, g,* fig. 39, which may be moved nearer to or farther from the drum, and from each other, by adjusting screws, as shown in the wood-engraving.

H, fig. 37, is a pair of fluted iron feeding-rollers, like those described for the blowing machine, which are pressed together by means of a screw, *c*; *h* is a feed-board, along the surface of which the fleece unwound from the lap-roll I, by the acting roller K, advances to the feed-rollers H. The first roller-card D, turning with much less velocity than the drum-card, draws in single filaments from the feed-roller, and is thence sometimes called the licker-in. These filaments are immediately stripped from it by the large cylinder, A, to be again teazed out by the teeth of the second roller or squirrel, E, moving still more slowly than D, and thereby serving to pick off the knots from the drum. These knots being carried round by the roller, are again presented to the cylinder D, as it revolves nearly in contact with E. The roller, D, next transfers the teazed-out filaments to the drum, blending them with fresh ones supplied by the feed-rollers. The tufts or knots which elude the action of the first two rollers, D and E, are pretty sure to be laid hold of by the fourth roller, G, because it is placed closer to the drum, and moves with the same speed as the roller E. The knots caught by G are teazed out by the roller F, which is nearly in contact with it, but revolves at a quicker rate, yet not so fast as the surface of the drum, F. The loosened fibres are thus seized by F, and once more transferred to the drum, whence they proceed and receive a second teazing from the roller, G. Should any knots still remain they will be arrested by the first flat top cards, and held there till they are disentangled by the rotation of the drum. On this account the first flats require more frequent cleaning than the subsequent ones.

The filaments, after emerging from the flats, lie in nearly parallel lines among the card-teeth of the drum, whence they are removed by a smaller drum-

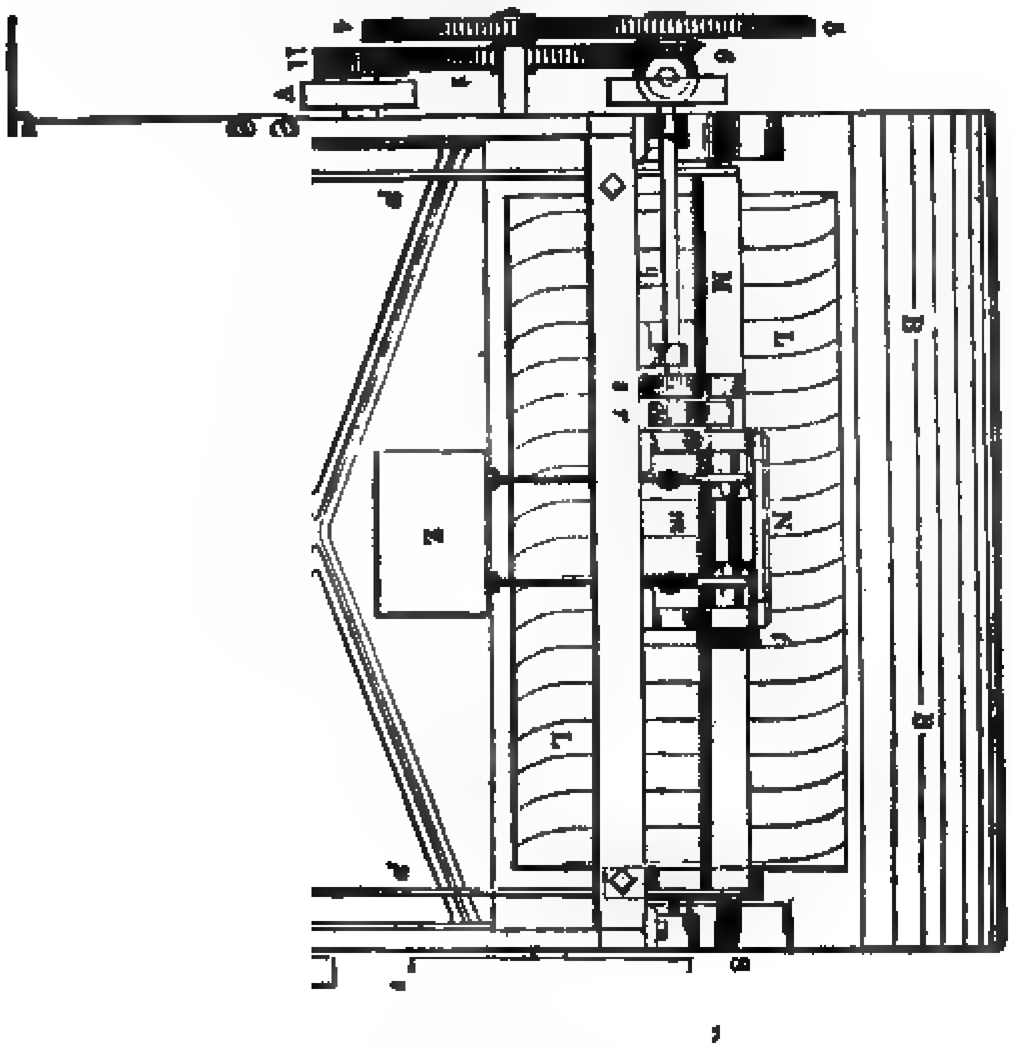


Fig. 32.—Carding Engine. Front view. Scale, three-fourths of an inch to the foot.

card, which turns in contact with it, called the *doffer*, (stripper), or doffing cylinder, L, and is covered spirally with fillet cards. By its slow rotation in an opposite direction it strips the loosened filaments from the drum, and thus clothes itself uniformly with a fine fleece of cotton, which is shorn or combed off from

the opposite side of the cylinder by the vibratory action of the doffing-knife, M. This mechanism consists of a blade of steel, toothed at its edge like a fine comb, and it is made to strike down, with a rapid shaving motion, tangentially over the points of the cards. This is the crank and comb contrivance so unjustly claimed for Hargreaves in the law-suit against Sir R. Arkwright. This elegant instrument takes off the cotton in a fine transparent fleece, like the aerial web or woven wind of Aurungzebe's daughter. Its breadth is equal to the length of the card on the doffer, but it is formed into a narrow riband, by being gradually hemmed in by passing through the funnel, *i*. This riband is called a card end (sometimes a sliver), and is drawn forwards by the first pair of rollers, *k*, in that part of the engine marked N. This apparatus consists of three pairs of iron rollers, *k*, *l*, *m*; the bottom rollers of *k* and *l* are finely fluted or channelled, and their top ones are covered with two coats, the inner being flannel and the outer being leather. These top rollers are pressed firmly upon the under ones by weights hung upon their axes. The pair of rollers *l*, by moving faster than the pair *k*, has the effect of drawing and straightening the filaments. The card end, after being spread by the rollers into a flat riband, is again gathered into an elliptical sliver, by being passed through the vertical slit in the plate *n*, and being drawn through between the two smooth rollers *m*; which are but slightly pressed together. This card-end is of a very spongy texture, and very slightly coherent. It is allowed to fall down into a tin can, O, as it escapes from the front delivering roller. In some factories the

finished card-ends of several engines are wound, as they are delivered, upon large wooden bobbins, with tin-plate ends, in parallel layers, so as to form a series of ribands easy of application to the next machine—the drawing-frame. In other factories the whole of the card-ends pass into a covered square conduit of wood on the floor of the apartment, which is furnished with a series of friction rollers, in correspondence with the respective card-engines. The whole card-ends are finally conducted upon a large bobbin, and wound into a fleece of parallel ribands, ready, like the above, to be presented most conveniently to the drawing heads.

The motions of the carding-engine are produced as follows:—To the shaft of the main cylinder, exterior to the frame-work, the usual fast and loose pulleys P, are attached. Upon the same shaft, between each end of the drum and the frame, is one pulley Q, fig. 39, and another R, in dotted lines, fig. 37. The latter of these pulleys drives the card roller (the licker-in) D, and the former drives the card-roller or squirrel F. Upon the shaft of the main cylinder, A, there is another pulley, S, alongside of the steam-pulley, P, from which motion is given by a strap to a slender shaft, T, fig. 37, 38, carrying upon its ends two small cranks, which are connected by rods, *p*, with the doffer-knife. These rods are guided by two arms, *o*, which keep the knife close to the doffing cylinder, L, while the cranks make it vibrate most rapidly up and down. The shaft of the main cylinder bears upon the end opposite to its steam-pulley end, a pinion, 1, fig. 39, which works into a wheel, 2, on whose axis there is another pinion, 3, working in a wheel, 4, so as to produce a slow motion. The last

wheel drives the doffing cylinder, L, by means of the wheel 5. From the shaft of this cylinder motion is given to the squirrel cards, E and G, by means of a strap going round pulleys, between the squirrel-cylinders and the frame, as is shown by dotted lines in fig. 37. Outside of the frame, upon the other end of the shaft of the doffing cylinder, is a bevel wheel, 6, which drives the hanging or inclined shaft, U, as also, by means of the bevel wheels, 7 and 8, the inferior feeding-roller, H. From this roller, motion is given, by a carrier wheel, 9, to a wheel, 10, upon the roller, K, which serves to wind off the fleece from the lap-roll. The wheel 2, formerly mentioned, drives another wheel, 11, below it and of course the pulley on its axis, whence motion is communicated to the drawing apparatus, N, as shown in figs. 38 and 39.

The shaft *q*, fig. 38, bears upon its end two wheels, of which one, *r*, gives motion to two small wheels fixed upon the ends of the two under rollers of the pairs *l* and *m*. The other wheel, *s*, drives a larger wheel upon the end of the under roller, *k*, so as to give a slower motion to this pair of rollers than to the two former pairs, both of which have nearly the same velocity, as *m* is but slightly larger than *l*, and therefore has a surface motion little greater. To prevent the two rollers at *m*, from sliding upon each other, little toothed-wheels, *t*, fig. 38, are fixed to their ends, so as to work into each other.

In many factories the cylinders are not constructed of wood, with iron framing, but are made entirely of cast-iron, and are coated with a cement composed of chalk and glue, which is somewhat harder than Paris plaster. Into holes drilled in the iron cylinders, wooden pegs are fixed for receiving the nails or pins which are used to fasten on the sheet or fillet-card leathers.

We have already mentioned that, in many of the coarse-spinning, and in all the fine-spinning factories, two sets of card-engines are employed, called the breakers and the finishers, which do not differ in any essential respect, except in the fineness of the card-teeth. The breaker delivers or winds its thin continuous fleece of cotton as it is combed off from the doffer, without narrowing it, upon the periphery of a revolving wooden roller. When this has received such a number of layers as constitutes a pretty thick coat, the fleece is torn asunder at the doffer, and the clothed roller is removed to the feed roller of the finisher card. When the ends from several cards are to be wound together on a large bobbin, their course is frequently guided by a series of smooth pins, or spiral channels; and then coiled round a roller in parallel ribands. The movable tin-plate ends of these bobbins being taken off, and a round wooden pin being substituted for the bobbin itself, the lap of parallel card-ends is ready to be presented to the feed-roller or licker-in of the finisher-card. In other cases, the card-ends of the breaker-cards are introduced directly from the cans in which they were received in parallel lines to the finisher-cards to save the winding-on process.

Fig. 40, the old carding-engine, surrounded with urchin-cards.

A, the drum; *a*, the feed-apron; *b*, *b*, moving rollers of the apron; *c*, *c*, feed-rollers; B, first urchin which takes the cotton off, and returns it to the drum; C, C, working urchins; D, D, cleaning urchins. By repeated transfers from one of these card-cylinders to another, and by a continual drawing out between the teeth of the different orders of cards, the cotton fila-

ments, (for low counts,) become separated and expanded. E is the doffer cylinder which strips the cotton from the drum; F, the steel comb or knife for taking the fleece off the doffer in a semi-transparent web. G represents a fluted cylinder, which is not employed in the cotton, but only in the woollen manuture, for making the card-rolls.

Here we have a carding-engine, with the drum surmounted with urchin or squirrel cards instead of

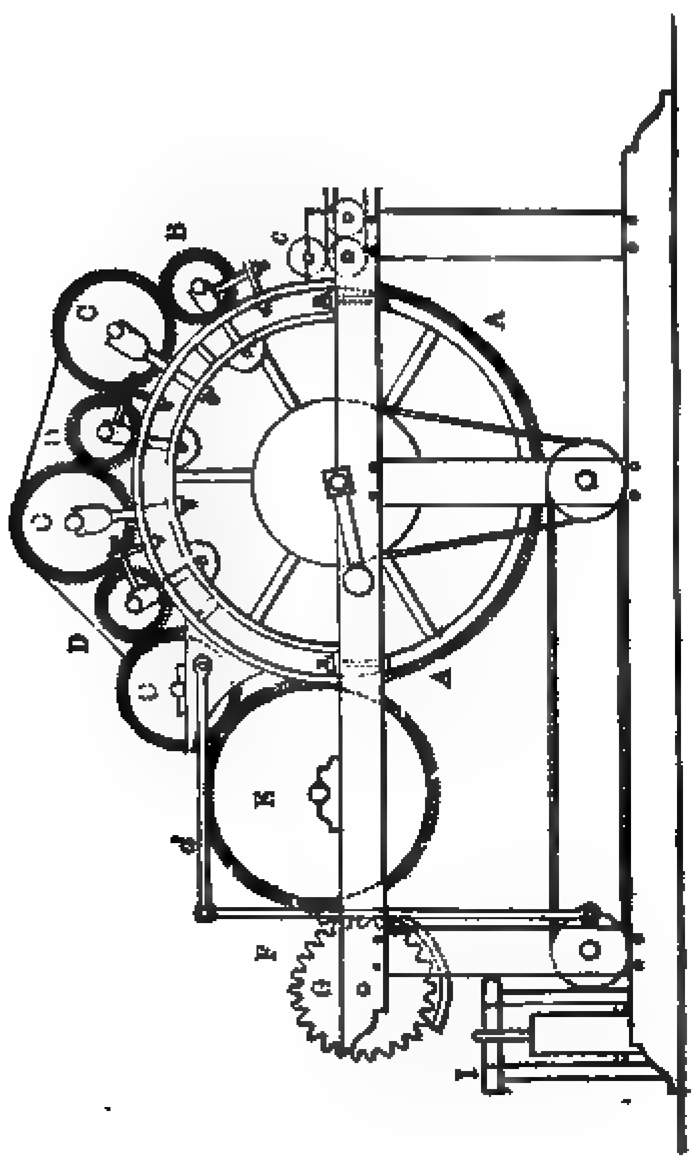


Fig. 40.—Carding Engine, surmounted with Urchin, or Squirrel Cards.

tops, such as are used in the preparation of inferior cotton wools for spinning coarse yarns. The principles of its mechanism are similar to those above described.

The speed communicated by the driving shaft to the main drum is not the same for every different staple of cotton. As carding is intended to open up the filaments, to undo their knots, and to shake out the dust, it would not answer its purpose perfectly were it performed with either too great or too small a velocity. It is the duty of the overlooker of the preparation-room to study the cotton wool in hand. It is obvious that tufts should not be disentangled too forcibly on the one hand, and, on the other, the filth adhering to the staple cannot be shaken off by too slight a degree of motion. The main drum must therefore be made to revolve, according to circumstances, from 120 to 150 times in a minute. Nor are the velocities of the other cylinders relatively to the principal one to be invariable; they require also to be modified. Supposing for example, that the latter has a speed of 130 in the minute, the different movements both of the axes and of the surface of the cylinders, which is the point to be considered, may be regulated as follows:—

While the drum card makes that number of turns, the feed-rollers should make only two-thirds of a revolution, so that the doffer shall deliver about sixteen feet of lap;—the first pair of drawing rollers should draw it about 26 inches, being the difference between 232 inches and 206 inches;—between the first and the delivering pair of drawing rollers, the card-end should suffer an elongation of 210 inches, being the difference between 442, the surface-speed of the last pair, and 232, the surface-speed of the

first pair;—the last smooth roller should draw it 11 inches more; and, finally, the ratio of the speed at the circumference of the feed-rollers, to that of the smooth delivering roller, should be as 26 inches are to 442, or as 1 to 17.

The card-engine being charged with a lap roll of perhaps 32 feet in length, weighing about 5 pounds, must be passed entirely through in 15 minutes; and the 32 feet of lap will form a card-end at the smooth roller of nearly 540 feet, of which one-fifth part, or one pound, will measure 108 feet; about three per cent. may be allowed for waste.

Long-stapled cottons require more carding than the short, on which account the drum is made to turn more rapidly, while that of the other cylinders is left unchanged, or even made to revolve more slowly. Such changes, however, are introduced only between the feed-rollers and the main-drum, or between the great drum and the doffer, whence a variation is produced in the grist of the card-end, the count of which must always be attended to.

Card sheets are distinguished by the number of wires in each breadth of three inches and a half for the drum, and two inches for the top cards; hence, in the former there will be 70 wires in all, or 20 per inch. The numbers of wires per inch, counted in the length of the sheet-leather, are called crowns. For the preparation of yarns below 36 hanks in the pound, the cards have 80 wires per sheet for the drum; the first, second, and third tops 20; the middle tops 26; and the last 28. For the preparation of yarns of 100 and above, the cards have from 90 to 100 wires per sheet for the drum, and so on in proportion.

The drum revolves with a surface velocity of from 20 to 30 times quicker than the doffer, according to the nature of the cotton. By measuring the parts of figures 37, 38, 39, which are most exactly delineated, to a scale of three-quarters of an inch to a foot, the relative magnitudes and velocities of every part of the carding-engine may be readily determined.

The tops of cards should, after cleaning, be laid down in their places with a delicate hand, and tested by a gentle pressure, to ascertain that they barely touch without catching the teeth of the revolving drum. I was told by a skilful spinner that a fluted feed-roller is not nearly so good as a pair of cylinder cards from two to three inches in diameter, with their teeth set inwards, so as to operate as lickers-in. They should be surmounted by a cylindrical card of larger dimensions, as shown in the figure, for taking off the cotton fibres and transferring them to the drum.

A patent was taken out a few years ago for travelling card tops, with a self-cleaning apparatus, but it was considered by the above gentleman to be a hazardous expedient. Double cards are now made 42 inches in the diameter of the drum, and 36 inches in length; single cards are half that length, or about 20 inches. I have seen many card-ends wound up continuously upon one large bobbin or roller 12 inches long, in parallel ribands, to form a lap for the drawing-frame.

In a *fine* spinning-mill at Manchester, seven finisher cards turn off 150 pounds of cotton (Sea-island) in 69 hours, or one week. Three yards of the lap presented to these cards weigh only four ounces. These seven finishers correspond to six breaker-cards; for a preparation as it is called (one set), 12 card-ends

go to form the first drawing. In the breaker-cards, 1,600 grains' weight of cotton are spread out upon seven feet of the apron-cloth, to form one lap.

In such an establishment, 150 pounds constitute as we have said, a preparation, which is confined to its peculiar set of cards, of drawing and roving frames. One man superintends four such preparations. The total wages for the preparation work of these 600 pounds of cotton wool is £11. 11*s*.

In a mill at Manchester, where fustian yarns are chiefly spun of No. 30 weft and No. 40 warp, the carding-engines are surmounted with urchin-cards, and do each to the amount of 1,000 pounds per week. The drum makes 180 revolutions per minute. Each card supplies 15 tubes of Dyer's roving-frame, equivalent to 800 throstle spindles.

For coarse spinning, where the card-ends are not received in cans (to save hand-labour), the card delivers its end on a roller, which rests on a horizontal carrier wooden drum. One bobbin roller usually takes on two ends together, through a guide funnel, which is carried at the extremity of a traversing arm, moved by a pinion, which works in a horizontal gridiron rack, alternately to the right hand and the left, upon the upper and under surface of the rack; whereby the double card-ends are wound in parallel rows, without crossing each other. Four of these large bobbins, thus filled with card-ends, are laid in horizontal frames, from which they deliver their ends to one drawing head, wherein eight ends are again combined through one guide funnel, and, after drawing, are wound upon another large bobbin, also revolving in a horizontal plane by the friction of a carrier

c', their respective top rollers; the former turn in brass bushes fixed upon iron bearings *d*. The front roller-beam F is fixed, but the bearings of the two other rollers may be shifted in grooves, so as to make these rollers approach to, or recede from, each other, and from the front roller, till the adjustment of their mutual distances suitable to the length or the staple of the particular cotton-wool be attained; when the bearings are made fast in that situation by the screw-nut *d* acting upon the edges of the slots in the slide-bearers. This adjustment constitutes an important improvement in the construction of the machine; because, not long ago, these two bearings were so connected as to move together at an invariable distance, and to be thus jointly adjustable only to the front roller. But in the machine here represented, the intervals between each two of the three rollers may be varied within proper limits at pleasure. The slot piece *d* adjusts the roller *a*, and a similar slot piece at the other side of the head adjusts the roller *b*.

The length of the top rollers is equal to that of two fluted portions of the under rollers, as plainly seen in fig. 42; and the top rollers turn with their necks in bearings, which are adjustable in a similar way to the bearings of the under rollers, as shown also in fig. 42. In the middle of each top roller, a', b', c', fig. 44, there

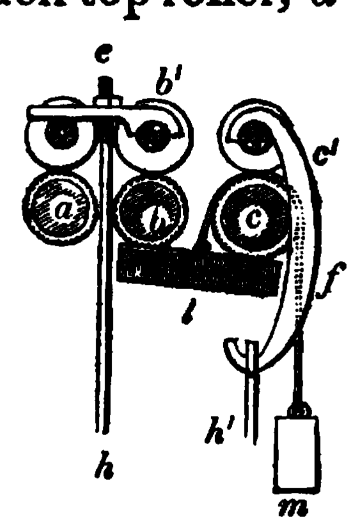


Fig. 44.—Pressure of Top Rollers.

is a smooth neck, upon which the brass bushes e, f, rest, suspending weights $g\ g'$, fig. 43, by wires $h\ h'$, fig. 43, 44. In general, the two back rollers, which turn most slowly, are pressed down by one common weight, while the front roller is pressed by a separate one. The three top rollers are covered with a mahogany bar i, faced below with flannel cloth for the purpose of wiping off any stray filaments which may tend to adhere to the top rollers. A corresponding bar l, also about an inch thick, faced with flannel above, and as long as one head, fig. 42, is made to bear by a light weight, m, fig. 44, upwards against the two front rollers b and c, to wipe them also from stray filaments. The cord or wire from m is seen going over the neck of the roller c, and down again to suspend the wiper-bar of mahogany l.

In figs. 41 and 43 G represents a smooth curved brass or tin plate, seen separate in plan in fig. 45,

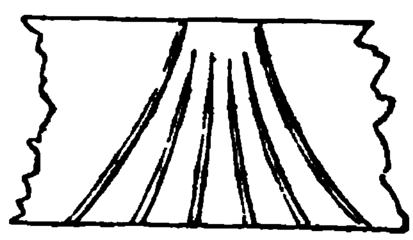


Fig. 45.—Drawing Frame; curved guide plate of the drawings.

along the channelled surface of which the slivers (porous ribands) n, n, fig. 43, from the respective cans H, H, standing at the back of the machine, are introduced to the rollers, and are kept apart by the pins o, fixed upon a brass bar p, figs. 41 and 43. In this way from three to six slivers may be brought together and united upon one fluted portion of the under rollers. In fig. 45 the same end is seen to be effected by a plate having converging channels, sepa-

rated by ridges, to guide several slivers in upon one fluting.

This compound or sextupled sliver, in passing between the roller series, is drawn out most particularly by the front roller into a uniform, somewhat attenuated, and much elongated sliver. Of such slivers, usually two are again brought together in a funnel I, and delivered by the two smooth rollers K K′, into a can L, standing in front of the machine. Occasionally one of the slivers, just after its delivery, is turned back over the smooth roller K′, and united with the slivers entering the funnel of the adjoining drawing. The smooth roller K turns in bearings of the frame M, which is attached to the roller-beam B, and supports the funnels I. The top roller K′ presses upon the other by its own weight, and is turned from the under roller by wheels *q q*, fig. 42, fixed upon their ends. The purpose of this funnel and long pair of smooth rollers is to collect, into a compact riband, the cotton filaments which were previously spread broad and thin between the drawing rollers *a, b, c*. Hence those rollers must have a surface velocity equal to that of the front fluted roller *c*. The motions of the machine are produced in the following way:—N represents the usual fast and loose pulley in the prolongation of the front roller shaft. The steam-pulley receives motion by a strap from the pulley D, upon the horizontal shaft C. Upon the same front roller-shaft is also fixed the pinion 1, fig. 43, driving, by the carrier (intermediate) wheel 2, the wheel 3, on the end of the smooth roller K. Upon the other end of the shaft of the front fluted roller *c* is a pinion, (figs. 41, 42,) driving the shaft O, (figs. 42, 43,) by means of the wheel 5. Close

to the last wheel, and upon the same shaft, is another smaller wheel 6, which drives a larger wheel 7, made fast to the prolongated middle roller *b*. Upon the other end of the shaft O is a wheel 8, driving the wheel 9, which is attached to the back under roller *a*.

A convenient and common mode of increasing the speed of the front roller *c*, without being obliged to use wheels too much differing in diameter, is to make that roller somewhat thicker than the others; so that it may be one inch and one quarter, or one inch and three-eighths, while the others may be from seven-eighths of an inch to one inch. The ratio of the sur face speed of the front roller *c*, to that of the back roller *a*, varies from 4 or 6 to 1; and that ratio may be modified by changing the wheels according to the size of the sliver that is desired. The difference between the speed of the two back rollers *a* and *b* is inconsiderable, being no more than one-tenth part, or thereby; the middle one serving rather as a guide in leading the filaments to the front roller.

The drawing tenter must be very careful to mend the feeding sliver-ends whenever any one of them breaks, and to stop the machine by sliding the strap upon the loose pulley at N, in case the delivering roller be in fault.

The drawing rollers above mentioned are cylindrical rods, subdivided into fluted portions, to each of which one sliver is assigned, as shown in fig. 42. Two such portions are covered with a top roller, having a narrow neck in its middle part, and resting at its ends or journals, in slot-bearings which lie between the fluted portions of the under rollers, as plainly seen over I I, in fig. 42. Upon each neck of the front top

roller is a brass hook, c', fig. 44, to which a weight, h', is hung, whilst another weight, at h, acts upon the centre of a brass plate (under e) resting upon the necks of the two upper back rollers, a', b'. The slot-bearings of the top rollers are attached to a bar, p, at the back of the rollers, which is fixed with its axis in the drawing heads, F (figs. 41 and 43), which the under rollers rest upon, in order to turn them round, if the latter are to be taken out.

The scale of figs. 41 and 42 is 1 inch to the foot; that of 43 and 44 is 2 inches to the foot.

Having explained the structure and general action of the drawing frame, it may be worth while to examine the changes it produces on the cotton staple a little more minutely.

Were the surface velocities of the three rollers, a, b, c, fig. 43, equal, the card ends, n, n, after gliding over G, would pass through to the funnel i unchanged. But the velocity of b and c being greater than that of a, the former will deliver a greater length of riband than they receive from the first, or than this receives from the cans, H, H. Under these circumstances the only result must be a proportional extension of the riband or sliver, in the intermediate space between a, b, and c, and an approximation of the filaments to rectilinear parallel directions, during this stretching process. The rollers are so adjusted, as we have seen, that the drawing takes place chiefly between the first and the third pair: in fact, the middle pair can have no influence in the drawing power beyond the difference of the first and third. The intervals between a, b, and c, or between their lines of contact with the upper rollers, should be in all cases calculated so that

they may exceed the average length of the cotton filaments; and so that these filaments may not be placed in danger of being torn by the third pair pulling, while the second pair has a firm hold of their other ends. Between these two pairs of rollers, however, where the principal drawing occurs, the distance should be no greater than is absolutely necessary to render the drawing out of the fibres alongside of each other practicable without their disruption; this adjustment being requisite to the uniformity of the drawing operation. Were that interval too great, it is obvious that a sliver in running through the rollers would become attenuated in the middle point between them, or might possibly break asunder; hence the drawing will be the more regular, the more nicely the interstitial space between the rollers is adapted to the length of the staple of the cotton. When one end of a filament, after being ushered in by the back rollers, is laid hold of by the second or middle pair, it is twitched suddenly forwards in a very gentle manner, so as to stretch it very slightly; but when advancing, it is seized by the front pair, and is more forcibly pulled at one end, while it is held at the other by the friction of its fellow filaments detained by the slower rollers; the distances of the different rollers being previously adjusted exactly to the average length of the staple. The sliver thus drawn, with multiplied doublings, acquires a regularity of texture which, if not impaired in the subsequent processes, ensures a level yarn to the cotton-spinner.

Were the drawing of a single sliver attempted to be continued until the suitable parallelism of its filaments were effected, it would ere long become an im-

possible operation, on account of the excessive attenuation of the riband. This inconvenience is obviated by the very simple method of associating at each repeated drawing several of the formerly-drawn slivers together into one riband: this is the process called doubling. It is an accurate imitation of what happens when we take a little cotton wool between the fingers and thumb of one hand, and draw it out with those of the other, at each turn laying the two parcels parallel again. The doubling secures the great advantage of causing the unequal parts of slivers to correct one another, and to produce finally a very uniform riband.

In the preparation department for spinning the mean counts of 36's or 40's, three drawing heads are appropriated to each card, and the doubling upon these heads is as follows: $\frac{6}{1}$; $\frac{6}{1}$; $\frac{9}{1}$, constituting one multiple sliver after 324 doublings.

In other good factories, four drawing heads go to one card, and these supply slivers to one coarse-bobbin and-fly frame, and to three fine frames.

Some manufacturers have lately introduced a double roller beam, and a double draught at the same doubling, into their drawing-frames. I have seen this contrivance working satisfactorily in mills where low numbers were spun, and where the tube-roving frame was employed; but I was informed, by competent judges, that it was not advisable where a superior fabric of calicoes for printing was manufactured.

In another factory, I found that 2,000 pounds of Bowed Georgian cottons were put through seven cards (breakers and finishers) weekly, which supplied

work to three drawing heads; and to one coarse, and two fine bobbin-and-fly frames. The numbers spun were 20's.

In the finest spinning mills, the doublings at the drawing frame are far more numerous, of which the following numbers form a good example:—

$$\frac{8}{1};\ \frac{4}{1};\ \frac{7}{1};\ \frac{6}{1};\ \frac{6}{1};\ \frac{6}{1}.$$

If these numerators, which indicate the number of slivers united at each successive drawing, be multiplied together, they will give the product 48,384; to which may be added another doubling at the coarse bobbin-and-fly frame, or the stretcher mule, constituting in all nearly 100,000 times that the fibres are repeatedly placed parallel to each other before a thread is attempted to be spun. Such is the mechanical refinement, of which the conception is originally due to the genius of Arkwright. It gives mathematical equality to the most irregular, and, at first sight, evanescent filament. In such a fine mill, the first head furnishes drawings for the next two heads; the second and third heads supply the fourth and fifth heads. There are indeed sometimes seven successive drawing and doubling operations.

Suppose that in a drawing-frame of four heads the extension or draught operated upon the sliver in each is as the number 4.65 to 1, we shall have the following ratio:—

$$\frac{6}{4.65} \times \frac{6}{4.65} \times \frac{6}{4.65} \times \frac{5}{4.65} = \frac{1080}{446.16} = 2.31$$

Hence, with 1,080 doublings, the card-end has become 2.31 times heavier or stronger. It had originally a weight corresponding to number 28 upon our scale of counts; and it has become $\frac{28}{2.31} = 12.1$, showing that

many more filaments are now arranged in nearly the same-sized riband, in consequence of their condensation, from being straightened and laid closely parallel. In the drawing operation there is no sensible waste of the cotton wool.

Nothing is easier than to change the relative velocities of the drawing machinery, by substituting, for the existing toothed wheels, others of a different count, either to increase or to diminish the number of the sliver. Drawing-frames are usually furnished by their constructors with these change wheels, which, by means of the shot and screw mode of fixture, are easily substituted for the others.

The mean velocity of the delivering-fluted roller is about 160 turns per minute, which, if it be 1¼ inch in diameter, or 3·95 inches in circumference, will give out nearly 53 feet per minute. Many of them discharge 60 feet per minute, or 1 foot per second.

SECTION IV.—Roving Frames.

After the process of drawing as just described, the next operation of a cotton-mill is the making a roving, or thin sliver, which is very tenderly twisted, at least in the course of its attenuation. In the tube-roving frame the twist is merely momentary. In this stage of the cotton manufacture, the utmost delicacy is required to preserve the evenness of the spongy cord, upon which the final levelness of the yarn depends. An incredible number of machines has been contrived, since the first elegant can-roving frame of Arkwright, for the purpose of performing this process with precision and speed. By means of that frame (see figs.

46 and 47) the slivers, after passing through the usual drawing rollers, where they were considerably elongated, received a slight twist from the revolution of the tin cans into which the rovings fell, and were distributed round its interior surface in regular coils by the centrifugal force. It is in fact the drawing-frame, fig. 41, with the receiving cans set in rotation upon a central pivot.

A, A, are the tin cans containing two sets of drawings in fig. 46, and several card-ends in fig. 47; *d*, *c*,

Fig. 46.—Can Roving Frame of Arkwright.

are the front pair of drawing rollers; *b*, *a*, the back pair (the middle being suppressed, for the sake of simplifying the illustration); *f*, *e*, in fig. 47, are the delivering smooth rollers; *g* is the funnel for contracting and rounding the sliver a little before it passes through the delivering rollers; B is the receiving can, where, in fig. 46, the coils of roving are exhibited. The can B has a door (left open in that figure) for

b d f

Fig. 47.—Common Roving Frame.

removing the rovings, when it was filled. They were then taken by girls and wound upon bobbins, with the aid of a simple machine, called a winding-block, also the invention of Arkwright. Sometimes the cans were made of what was called the skeleton kind, so that the interior cage-frame could be taken out full of roving, and carried to the winding-block. This was an improvement, as it saved the risk of injuring the tender rovings by handling them. At other times, these skeleton frames were transported at once, and placed in connection with the next machine, in the factory series at the time, which drew out the contents slowly, as wanted, at the top orifice.

Very good yarn was made by Messrs. Arkwright and Messrs. Strutt with the aid of this roving apparatus, but in ordinary hands it was found to have many defects. The torsion was not equally diffused over the whole length of the roving; and the subse-

quent winding or drawing out of the cans injured the rovings, if they were equally twisted. Considerable expense was also incurred in the winding process.

To obviate these evils, the Jack-frame, or *Jack-in-a-Box,* was contrived—a very ingenious, but rather complex mechanism, and therefore liable to frequent derangement. Fig. 48 exhibits an outline of its con-

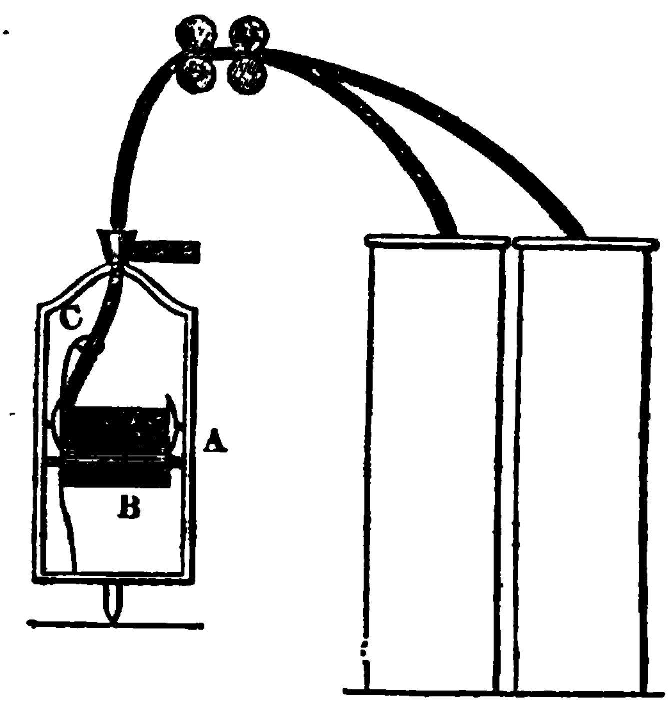


Fig. 48.—Jack-Roving Frame, or Jack-in-a-Box.

struction. B is the carrier cylinder, made to revolve by wheel-work (not shown here) at such a rate, that its surface velocity is the same with that of the front drawing roller; A is the bobbin lying upon it; C the guide-wire, with an eye at its end, which was made to traverse from right to left and left to right alternately, thus equalizing the distribution of the roving upon the bobbin. The vertical rotatory motion of the jack-frame upon its pivot, like that of the revolving can, gave the twist.

The jack-in-the-box was after some time superseded by the bobbin-and-fly frame—a contrivance upon the same principle as the flax or Saxon hand-wheel (fig. 16), already described, and which Arkwright, with

singular sagacity, sought to apply at the earliest period to cotton-roving; though he found the state of mechanical refinement then inadequate to realize this happy conception. But, in fact, this beautiful machine has arrived at its present state of perfection through more numerous efforts of ingenuity, and by the co-operative agency of a greater variety of individuals, than any other mechanism known in the cotton trade. The chief difficulty in these machines proceeded from the soft delicate nature of the roving, and the nicety required to wind it on at neither a faster nor a slower rate than the front-roller pair sent it forth. This nicety was increased by the ever-varying circumference of the bobbin within the flyer, as well as by the changes occasionally required in the degree of twist to be given to the roving for particular purposes. To accomplish these several objects, with precision and facility, was for many years a desideratum in cotton manufactories.

The peculiar functions of this class of machines may be arranged under two heads: 1, the twisting action; 2, the winding-on motion.

The twisting is effected by the revolution of the spindle (see fig. 49) F, to which the fly-fork is attached, while the sliver A, in its passage from the roller to the bobbin, proceeds along the hollow arm, H H, of the flyer, which, being of one piece with the spindle, revolves with it; the quantity of twist given to the roving depends upon the ratio between the surface speed of the front roller and the revolutions of the spindle. The winding-on was accomplished in jack-frames by a uniform motion applied by a carrier roller to the *surface* of the roving on the bobbin, which was

made to correspond exactly with the surface speed of the front roller ; but in the bobbin-and-fly frame it is

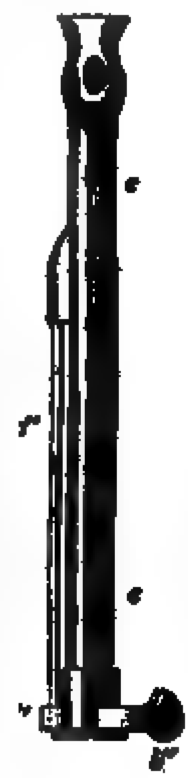


Fig. 41.——Spindle of Bobbin-and-Fly Frame, with Spring Presser.
Scale three inches to the foot.

accomplished by giving to the bobbin such a velocity that the difference between the motion of the surface of the bobbin, and the motion of the delivering end at the arm of the flyer, shall equal the surface motion of the roller, or the supply of sliver. This distinction between the action of the jack-frame (to which, in the winding-on, the tube-frame may be assimilated), and the bobbin-and-fly frame, must be constantly kept in view.

In the bobbin-and-fly frame the bobbin revolves round the spindle, and not at right angles to it, as in the jack-frame, which circumstance removes many of the objections justly urged against the latter contrivance. The first bobbin-and-fly frames were of a very complicated kind, containing three or four conical drums for producing the several variable motions. These were gradually diminished, and the whole was simplified, and reduced to the state in which we find it, first by the indefatigable labours of Messrs. Cocker and Higgins, the eminent engineering-mechanicians, and partly by the inventive ingenuity of Henry Houldsworth, jun., Esq., formerly of Glasgow, now of Manchester.

From the position of the bobbin upon the axis of the spindle, it is obvious that every revolution of the spindle or delivering arm of the flyer round the bobbin supposed at rest, or ahead of it supposed in motion, will wind up a length of roving equal to the determinate periphery of the bobbin, the end of the roving being previously attached to it. But as the number of revolutions of the spindle requisite to give the desired degree of twist has no necessary connection with, but, in fact, greatly exceeds the number of turns required

to wind up the length of roving delivered by the front rollers, it follows that, unless some scheme be contrived for lessening progressively the number of revolutions of the flyer round the bobbin, the roving will be coiled up too fast, and will be infallibly stretched and broken. This scheme cannot consist in reducing the number of revolutions of the flyer (for these must be proportional to the desired degree of torsion), but in making the bobbin revolve in the same direction with the spindle, but at a speed so much less than it as to cause the circumference of the bobbin to fall behind the delivering arm of the flyer, so that the difference of their velocities shall equal the rate at which the roving issues from the front roller. Thus, if a given length of roving, equal, for instance, to the periphery of the front roller, or four inches, be equal also to one circumference of the bobbin at a certain stage of its increase, then, to wind up this length, the arm of the flyer must revolve several times about the bobbin till it has got ahead of its surface rotation by four inches; and this may be effected either by making the spindle turn once round while the bobbin stands still, or by making the bobbin revolve one turn less than the spindle, whatever may be the speed of the spindle. If the spindle, for example, makes ten turns while the above four inches are given out by the rollers, then the bobbin will require to make nine turns; or, if the spindle makes twenty turns, the bobbin will require to make nineteen. The same result will be produced whatever be the speed of the spindle, provided the difference between the circular space, percurred by the spindle and the bobbin in the given time, remains four inches. This difference, which represents exactly the requisite wind-

ing-on motion, is, therefore, dependent jointly upon the speed of the front roller, or the delivering motion, and upon the size of the circumference of the bobbin at the particular stage of the winding-on, and is quite independent of the twist or the velocity of the spindle.

From the manner in which the first bobbin-and-fly frames were constructed, every change in the twist required a corresponding change in the speed of the bobbin—a change not proportional to that of the twist, but such as would preserve the difference between the motion of the spindle and bobbin as it was, relatively to the roller. Thus if the spindle, turning ten times while the bobbin turned nine times, gave the proper difference of motion = 1, for winding-on, then if the twist was doubled, the speed of the bobbin would require to be more than doubled, for, as the spindle would then turn 20 times, the bobbin ought to turn not 18, but 19 times, in order to maintain the same difference of motion = 1, as at first.

The object of the recent improvements of this important machine, for most of which the world is indebted to Mr. Houldsworth, has been to get rid of the difficulty of making these perpetually recurring and very intricate adjustments of the speed of the bobbin, which were found in practice to be beyond the capacity of most overlookers of the preparation-rooms of cotton-mills, who seldom arrived at the correct difference till after an expensive and wasteful series of errors and alterations, whereby the quality of the work was more or less damaged for several weeks at each change of the twist or of the cotton staple. It is only since these improvements of Mr. Houldsworth were introduced, about eight or nine years ago, that

excellent yarn has been turned off with increased uniformity and speed, so as to extend the trade by lowering the cost of producing a superior article. The good yarn formerly made, required prodigious pains in the first adjustment of the machine; and its quality could not be altered to suit a new market without extraordinary exertions on the part of the mechanics as well as the spinners of a factory.

Green, a tinman in Mansfield, who had been occasionally employed in a cotton-mill in the neighbourhood of that town, became acquainted with the difficulty now stated, and, being of a scheming turn of mind, hit upon the novel idea of connecting the spindle and bobbin together in such a manner as to be able to modify the speed of the bobbin, or to make it differ from that of the spindle, by a train of mechanism acted upon by the front roller, upon which, as already stated, the quantity of the winding-on motion depends. By this mechanism he was able at pleasure to regulate the difference of speed between the spindle and the bobbin, without reference to the velocity of the spindle; so that alterations of the twist did not, as formerly, require any altered adjustment of the bobbin motion.

The difference between all the old constructions and this new one may be illustrated popularly as follows: —Suppose two ships, sailing in the same direction, one after the other, and that the pilot of the sternmost is desired to follow his leader at such a rate as to fall behind one mile every hour, whatever be the speed of the first ship. There are two ways in which the pilot may execute his orders: first, he may measure the speed of the leading ship, and regulate his rate of sailing accordingly, but this would be a very difficult

if not impracticable undertaking; secondly, he may attach a line to his leader, and let it out at the rate of a mile per hour. Thus he would make sure work; but, if he adopted the first plan, he would require to note incessantly the changed velocity of his leader, and study to slacken his own rate accordingly, so as always to recede a mile in the hour. By the second plan, all the concern and uncertainty of looking after the first ship would be superseded, and he might perform his task with equal certainty by night as by day.

This illustration will enable any one thoroughly to apprehend the difference between the old bobbin-and-fly frame movements, and those of Green; for if we consider the spindle in the old construction to be the leader, the bobbin the follower, and the mile an hour of retardation (the required difference of speed between the spindle and bobbin, in order to wind up the roving as it is delivered by the front rollers), then, by the first mode of piloting the second ship, we see exemplified the difficulty imposed upon the workman with the former machines, when changes in the twist, that is, in the relation between the speed of the spindle and the rollers, were required; but, on the second plan of sailing, we see the value of Green's idea of connecting the spindle and bobbin in such a manner that the required difference of motion shall be regulated and measured by the front roller, just as the rope connecting the two ships could be let out at a uniform rate, whatever changes were made in the speed of the leader, and of course of the follower. Mr. Green obtained a patent for his invention upon the 26th of June, 1823, and states in the specification that the object of his improvement in roving, spinning, &c., "is to retard in

a small degree the revolution of the bobbin, by which it shall revolve in the proportion of about nine times to ten of the spindle, and hence in every ten revolutions of the spindle the thread will be laid once round the bobbin." * I need not transcribe his description of the apparatus, as it could not be successfully brought into practice; not from any error in the general principle, which was sound, but from his manner of applying it. The great objections to its use were, first, that the complex regulating mechanism was applied to every spindle; and, second, that upon the stem of each spindle, below the bobbin, there were two tubes subjected to quick reciprocating motions, and thence very liable to become deranged, or to derange the bobbin and fly. A skilful mechanician, who gave the scheme a full trial, assured me that he was compelled to relinquish it in consequence of the accidents which perpetually happened to the studs that projected from the stem of the spindle, and worked in a spiral groove cut in the tube round the spindle-stem which carried the bobbins. These studs struck upon the tops and bottoms of this spiral groove, at every change of direction, with such violence, during the rotation of the spindles, as to break everything in pieces. In fact, any one may conceive that quick reciprocations of movement, with a spindle revolving many hundred times in the minute, must be inconsistent with mechanical stability.

The idea was not, however, lost to the world, for Mr. H. Houldsworth took it up, and invented in 1824 a method of communicating motion to the bobbins by smooth rotatory means, which removed completely the difficulties encountered by Mr. Green, and reduced

* Newton's Journal of Science, vol. viii., p. 284.

the bobbin-and-fly frame in this important particular to a simplicity and precision of adjustment accommodated to the capacity of any intelligent workman. Mr. Houldsworth obtained a patent for his admirable invention in January, 1826.

Before entering into a detailed description of this mechanism, which affords perhaps the most refined specimen of the automatic equating principle to be found in the whole compass of science and art, I shall advert to a point not sufficiently brought out in the preliminary elucidation. While the circumference of the bobbin is equal to that of the front roller, during the time of every turn of the latter the bobbin must make one turn less than the spindle, in order that it may take up the roving which has been simultaneously given out. Thus, if the spindle makes six turns for one turn of the roller, the bobbin must, in the same time, make five turns. But we must remember that the bobbin is perpetually increasing in size, so that, by every successive layer of the tender spongy cord, its motion requires to be quickened (otherwise it would take up too fast by its enlarged surface), so that the difference between its rotatory motion, and that of the spindle, shall become less. When the bobbin, for instance, is twice the diameter of the roller, its speed would require to be five and a half (instead of six, as at first), while the spindle still makes six turns, because one-half the circumference of the bobbin *now* is equal to the whole of it when empty, and to the whole surface motion of the front roller. Hence the speed of the bobbin, when empty, is to the speed of the bobbin, when so filled, as five to five and a half—a retardation which is effected

by causing the driving-strap to slide along the surface of a conical drum. This proportion does not, however, remain constant when a change of twist is to be made, and hence the cone motion was inadequate to remedy the defect, till Mr. Houldsworth's differential system was introduced along with it.

Description of the Bobbin-and-Fly Frame.

This beautiful machine, as constructed by Messrs. Cocker and Higgins, with these modern patent improvements, is represented in plate IV., and in figs. 49, 50, 51, and 52, and deserves the peculiar study of the philosopher, on account of its exquisite mechanical combinations. It consists of several organic structures, which may be separately considered. There is a roller-beam similar to that described under the drawing-frame, and there are vertical revolving rods of steel, called spindles, bearing on their summits a bifurcated piece, called a flyer, of which one leg is tubular, and serves to conduct the soft roving from the nose of the spindle to the bobbin (see fig. 49). By the revolution of the spindle and flyer the cotton slab receives its twist, and by the difference of the rotation of the flyer and bobbin it is wound upon the latter exactly in proportion as it is given off by the rollers. The winding-on takes place in a ratio compounded of the difference of the speed of the bobbin and flyer, and of the circumference of the bobbin. Were the winding-on to be a constant quantity, like the motion of the delivering rollers, the product of the two numbers would remain the same; but when one of them alters, as happens to the diameter of the bobbin, which is constantly increasing, the other quantity, namely, the

difference between the number of revolutions of the bobbin and the flyer, must be decreased; a change produced by increasing the speed of the bobbins, while the flyers revolve uniformly, in order to give a uniform degree of torsion to a definite length of the delivered slab. As, therefore, the up-and-down motion of the bobbin, in the distribution of the roving over its surface, must be decreased in a constant progression according to the grist of the roving, so the rotation of the bobbin is increased by a motion compounded of the regular speed of the driving-shaft of the machine, and the decreased speed of the other parts.

Till lately the bobbins were formed of wooden tubes, with flat circular ends or discs, which confined the roving; but these discs are now discontinued, as they were found to injure the roving in various ways for the best work. In the most-recently made fly-frames the bobbins are simple wooden tubes, upon which the roving is wound, so as to produce conical ends, by shortening, after a certain period in the winding-on, the extent of the traverse, or up-and-down motion of the bobbin.

Fig. 50 exhibits that end of the machine where the motions are communicated. Fig. 51 is a cross section, taken parallel with the former view. Plate IV. is a part of the longitudinal back view, containing all the working gear. The other parts (not shown here) are merely a series of spindles to suit the length of the space destined to accommodate the machine.

Two sets of bobbin-and-fly frames are generally used in the best factories, called the coarse and fine, or the first and second roving-frames; they are both the same essentially, but the first is generally con-

structed in larger dimensions, but with fewer spindles, and is fed with slivers from cans or large bobbins filled at the drawing frame, placed at the back of the machine. The second roving-frame is fed from the bobbins filled at the first frame, which are arranged on upright skewers in a shelf, called the *creel*, placed behind the roller-beam. This creel is shown in figs. 50 and 51; but it is left out in plate IV., to prevent confusion.

A is the fast and loose pulley which is connected by a strap with the mill shaft, as shown at *h*, in the transverse section of the mill, plate II.

B is a small fly-wheel to equalize the motion of the machine.

C is a horizontal shaft going nearly the whole length of the frame, as seen in plate IV., and producing all its internal motions.

D is a set of drawing rollers mounted upon a beam E, fig. 51, of exactly the same construction as that used in the drawing frame already described. The rollers are not, however, like them, divided between several independent heads, but are equally distributed along the length of the machine, from the one end to the other, and are supported at several places by bearings, similar to those seen at the right end of the figure, upon which they rest in collars.

F, F′, are the spindles arranged in two rows, through the whole length of the frame, in such a way that those of one line stand in the intervals of the other. These spindles are carried in the bearings *a, a*, fig. 51, and revolve upon the steps *b, b*. At their lower ends there are small bevel wheels *c, c*, which are driven by others *d, d*, fixed upon shafts which go from one end

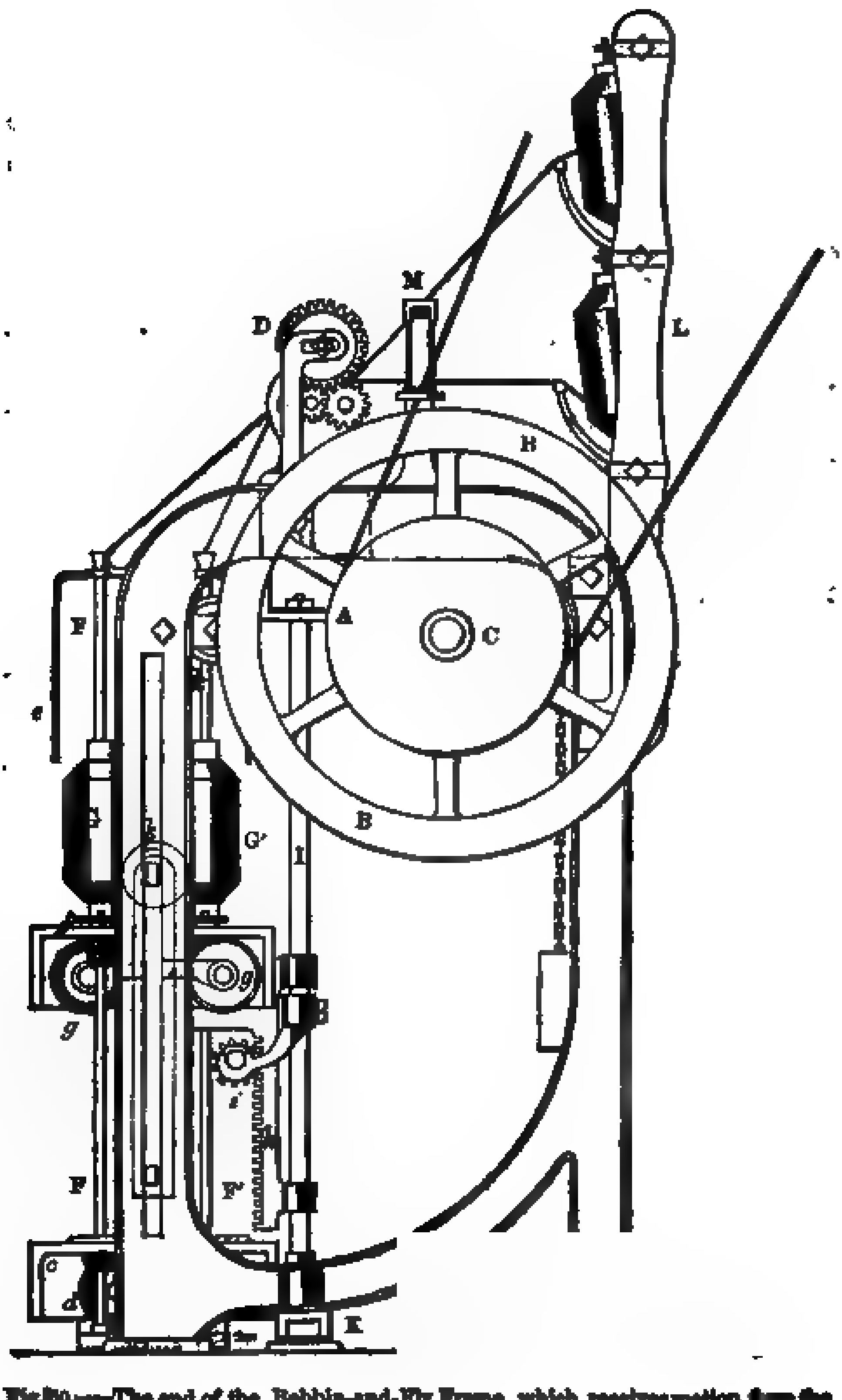


Fig. 30.—The end of the Bobbin-and-Fly Frame, which receives motion from the mill shaft by a band. Scale one inch to the foot.

of the machine to the other. In order to allow these shafts to run along side of the spindles, the teeth of these bevel wheels *c, c,* and *d, d,* are not cut in a line leading to the axis of their motion, but are cut as tangents to a circle, whose radius is equal to the distance between the centre of the horizontal shafts, and the centre of the spindle.

e, e, is the flyer, one arm of which is a tube with a slot to introduce the slab or roving, but the other is a mere rod to counterbalance the former, and to prevent its flying off or getting loose upon the spindle, upon the conical summit of which it is pressed after the full bobbins have been changed for empty ones. G, fig. 50, is the bobbin resting upon a plate connected with a small bevel wheel *f, f,* similar to the wheels *c, c,* upon the spindles, as above described. They are driven independently of the revolving spindles by other wheels *g, g,* fixed upon shafts which run through the whole length of the machine, and are moved by a mechanism afterwards to be described. The bearings of the shaft of *g, g,* and the upper bearings of the spindles, are fixed to a strong beam H, plate IV., which slides slowly up and down, carrying with it the shafts and wheels, which give motion to the bobbins. In this up-and-down motion the beam is guided by several rods I, I, which connect the roller-beam E with an iron beam K resting with feet upon the floor, and made fast to the frame work of the ends of the machine. It is raised by several racks *h,* fig. 50, in which pinions *i* work, on a shaft also running the length of the machine, and which get by turns a motion to the right and the left. The copping-beam H, which is covered with a casing of wood, which encloses also the shafts and wheels, is

Fig. 51.—Cross Section of Bobbin-and-Fly Frame, parallel with the view in fig. 50. Scale one inch to the foot.

counterpoised by weights suspended to chains going over the pulley *k, k,* fig. 51 and plate IV.

The sliver before entering between the back pair of drawing-rollers, is led through between two guides fixed upon a wooden bar, which has a very slow lateral traverse motion, so as to shift the sliver alternately to the right and left, about three-quarters of an inch, in order to prevent the leather covering of the top rollers from being indented or grooved by the slivers passing constantly over the same line of their surface. The motion is given to this bar, in this machine as well as in all the roller spinning-machines, by a little excentric, or a crank, fixed upon a toothed-wheel, which is moved by a snail-screw on the end of the axis of the back roller. See description of the throstle.

L is the creel, which serves in the fine bobbin-and-fly frame to carry the bobbins filled with the rovings made at the coarse frame. From the section fig. 51, it will be seen that this roving passes through wire-eyes, which extend the whole length of the machine, to protect it from being torn obliquely from the bobbins.

In the coarse roving-frame, the top of the machine behind the rollers is covered with a smooth plate, upon which the slivers glide towards the rollers. M is a rod stretching along over the machine, having at its extremity a guide for pulling the strap which drives the steam-pulley; this rod therefore serves, when slid to right or left, to put the machine into, or to throw it out of geer, as the *tenter* requires in the course of his work, at whatever part of the frame he may happen to be employed at the time. See plate IV.

In order to explain the manner in which this curious mechanism acts, we must first turn our atten-

tion to the principal shaft C, C, a portion of which is seen in plate IV.

The two motions, which do not vary during the action of the machine, are those of the drawing-rollers, and the spindles; the first giving off a certain length of sliver, and the other revolving with a constant velocity to give a definite degree of twist to the definite length of roving.

Upon the end of shaft C is fixed a wheel 1, which by means of the carrier-wheel 2, and the wheel 3, drives the shaft N, upon whose other end, and exterior to the right-hand framing, there is another wheel 4, which drives a wheel 5, fixed on the prolonged end of the front roller; a pinion 6, on the shaft of the same roller, drives by the carrier-wheels 7 and 8, a wheel 9, upon the back roller-shaft. From this shaft, motion is given to the middle roller by means of a carrier-wheel, and two wheels, of nearly the same diameter, upon the other ends of the roller-shaft, which end is broken off in the engraving, plate IV., but is seen in the end view, fig. 50.

10 is a bevel wheel fixed upon the shaft C, which by means of wheel 11, drives the upright shaft *l, l*, and by the bevel wheels 12 and 13, the short shaft *m*, near the floor. From this shaft, motion is transferred by spur-wheels to the first horizontal shaft, in order to drive one line or row of spindles, whilst itself moves the second shaft by means of two spur-wheels attached to them, and working one another. See plate IV.

To produce the up-and-down motion of the bobbins, there is a pulley O, movable along the shaft N. A key or wedge, sliding in a groove of the latter, attaches it to the shaft, and makes it revolve with it. This

pulley O, by means of a strap, turns the cone P, which receives a diminishing rate of motion, as the strap advances from the smaller to the wider end. *s* is a pulley, pressed by a weight against the strap to keep it tight, and which advances with the other pulley O. The cone drives the shaft Q by the wheels 14 and 15; and from these, by the wheels 16 and 17, it drives the upright shaft R, which by the intervention of the small bevel wheel 18, drives either of the wheels 19 or 20 on the shaft S. One of them is shifted into geer with it by an apparatus, to be described hereafter. The shaft S is driven by these means to the right or to the left, and therefore turns, also, the pinion 21, at its end. The wheel 22 is made fast to the shaft with the pinions *i, i,* so as to move the latter, either in the one or the other direction. The alternate up-and-down motion, formerly mentioned, is thus communicated to the copping-rail, which carries the bobbins. See I, I, in plate IV.

The shaft Q has at its end a pinion 23, which

Fig. [illegible].—Equational Mechanism of Mr. Houldsworth's Differential Box in the Bobbin-and-Fly Frame. Scale two inches to the foot.

works in a toothed part of the apparatus T, called the differential box, being the subject of Mr. Houldsworth's patent. It is represented separately in figs. 52, 53, and 54. O' is a wheel, plate IV., revolving loosely upon the shaft C, figs. 52, 53, and 54, having

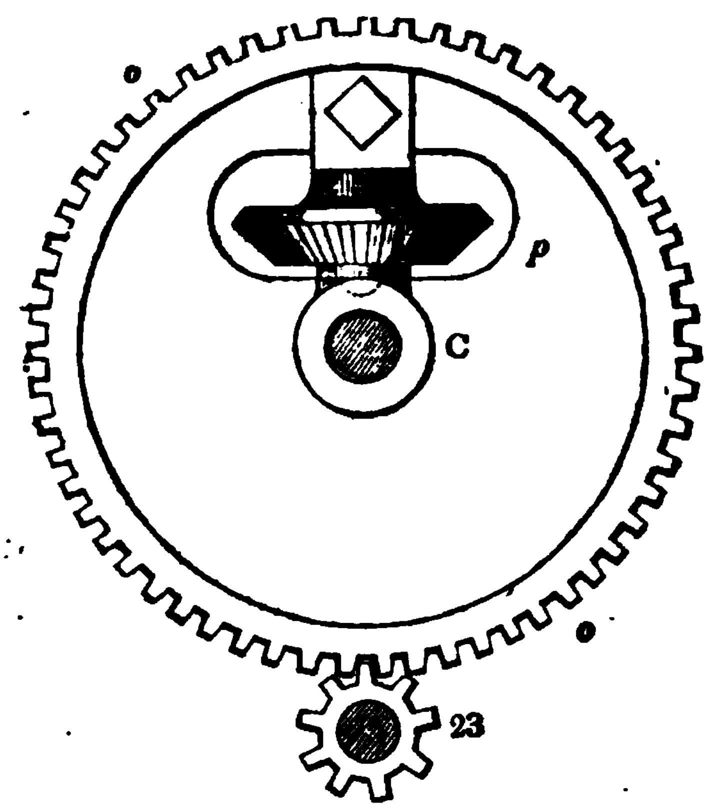


Fig. 53.—Equational Mechanism. Scale two inches to the foot.

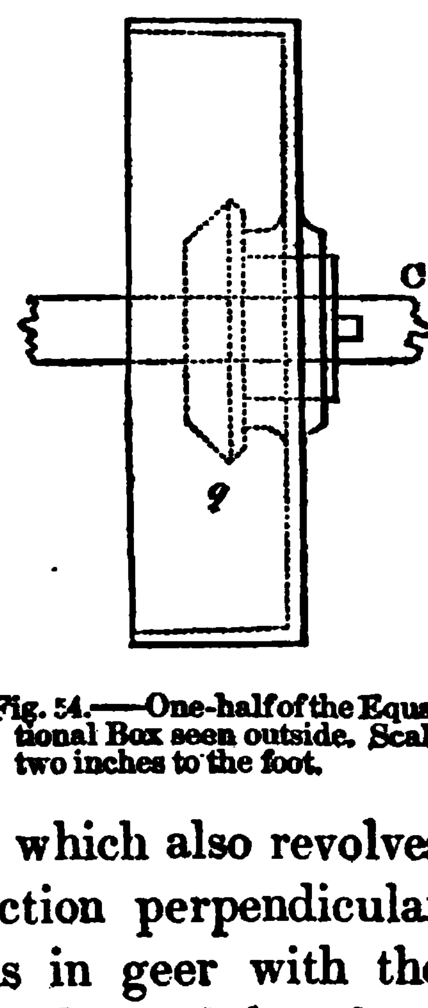


Fig. 54.—One-half of the Equational Box seen outside. Scale two inches to the foot.

attached over it a bevel wheel *p*, which also revolves loose upon its own axis in a direction perpendicular to C; *q* and *r* are bevel wheels in geer with the bevel wheel *p*, whose axis is in the plane of the wheel *o*, and goes round with it; *q* is fixed upon the shaft C, but *r* revolves loose upon C, and is connected with wheel 24. This apparatus is enclosed within two hollow cylinders, which join together to form one cylindric box; each cylinder has one of the bevel wheels *q* or *r* fixed to it: these boxes joined serve to support the large spur-wheel *o*, which forms the middle part of the cylindric box.

Suppose now that the wheel *o* were stopped, it is

obvious that the bevel wheel *q* would drive *r*, by the intervention of *p*, with the same speed, but in a contrary direction; should the wheel *o*, however, also revolve in the same direction with *q*, and with the same velocity, it is manifest that no motion at all would be transmitted to the wheel *r*, which would therefore remain at rest, while encircled, as it were, with motion. But if the wheel *o* turns more slowly than *q*, the wheel *r* will necessarily be made to turn with a velocity equal to the difference between the speeds of *q* and *o*. By gradually decreasing the speed of *o* (in proportion to the fineness of the roving) the wheel 24 will be turned with a velocity equal to the difference between a uniform motion (that of the spindles) and a variable motion (that required for the increasing diameter of the bobbins). From wheel 24, motion is transmitted to regulate that of the bobbin in winding the roving upon it, agreeably to the principles formerly stated. The wheel 24 drives by the two carrier-wheels 25 and 26, a wheel on the first horizontal shaft for driving the bobbins, shown by dotted lines in fig. 51. From the first shaft motion is given to the second by two spur-wheels 27 and 28, fixed upon the ends of the shafts, and working in each other.

While the great copping-beam H, with the shafts attached to it, works up and down, the contact or geering of the wheels 24, 25, 26, is preserved, as well as that of the dotted wheel on the shaft *g*, fig. 51, by means of two arms *s* and *t*, (to the left of the line of wheel-work 24, 25, 26, in plate IV.,) jointed at one of their ends, turning loose at the other end upon the shafts *g* and C, and having fixed upon them the

central studs for carrying the wheels 25 and 26 (as is clearly shown in fig. 51, and in plate IV.).

We have now to show how the pulley O, with its tightening pulley *n*, is gradually shifted, or made to slide along the shaft N, in such manner as to communicate a variable motion to the cone P, and to cause it to turn progressively slower as it approaches its apex or summit. *u* is an oblong slot-plate of cast iron, screwed fast against the roller-beam E. On its slot-face another piece *v* is fitted, so as to be susceptible of a sliding motion. The upper and under edges of this piece are notched with ratchet-teeth, in which two clicks *x* and *y* work. A perpendicular arm or branch *w* of that slide-piece can be adapted to it, at any height, by a bolt *a′* with the lever Z, turning on the joint *b′*. To the top *c′* of the lever a long horizontal rod *d′* is attached, which connects it with the guide-groove, in which the pulley O moves upon the shaft N. From the same point a rope proceeds and runs over a pulley *e′*, suspending a weight *f′*, for drawing the lever Z in the direction of the arrow (plate IV.); whence, by lifting one of the clicks *x* and *y*, a tooth of the slide-piece *v* escapes, and the other click catches the next tooth of the rack. The successive lifting of one tooth after another, is performed by an upright rod *g′* being moved a little up and down by the apparatus U, which is delineated separately in plan (see fig. 56), and in a front view (fig. 55). It is shown in a back view, in plate IV., in connexion with the whole machine. H, H, is the copping-rail for moving up and down all the bobbins simultaneously, to which is attached the piece *h′*, which by means of the straight slot above Z, moves the lever *i′*, sliding in a staple-piece, which

Fig. 55.

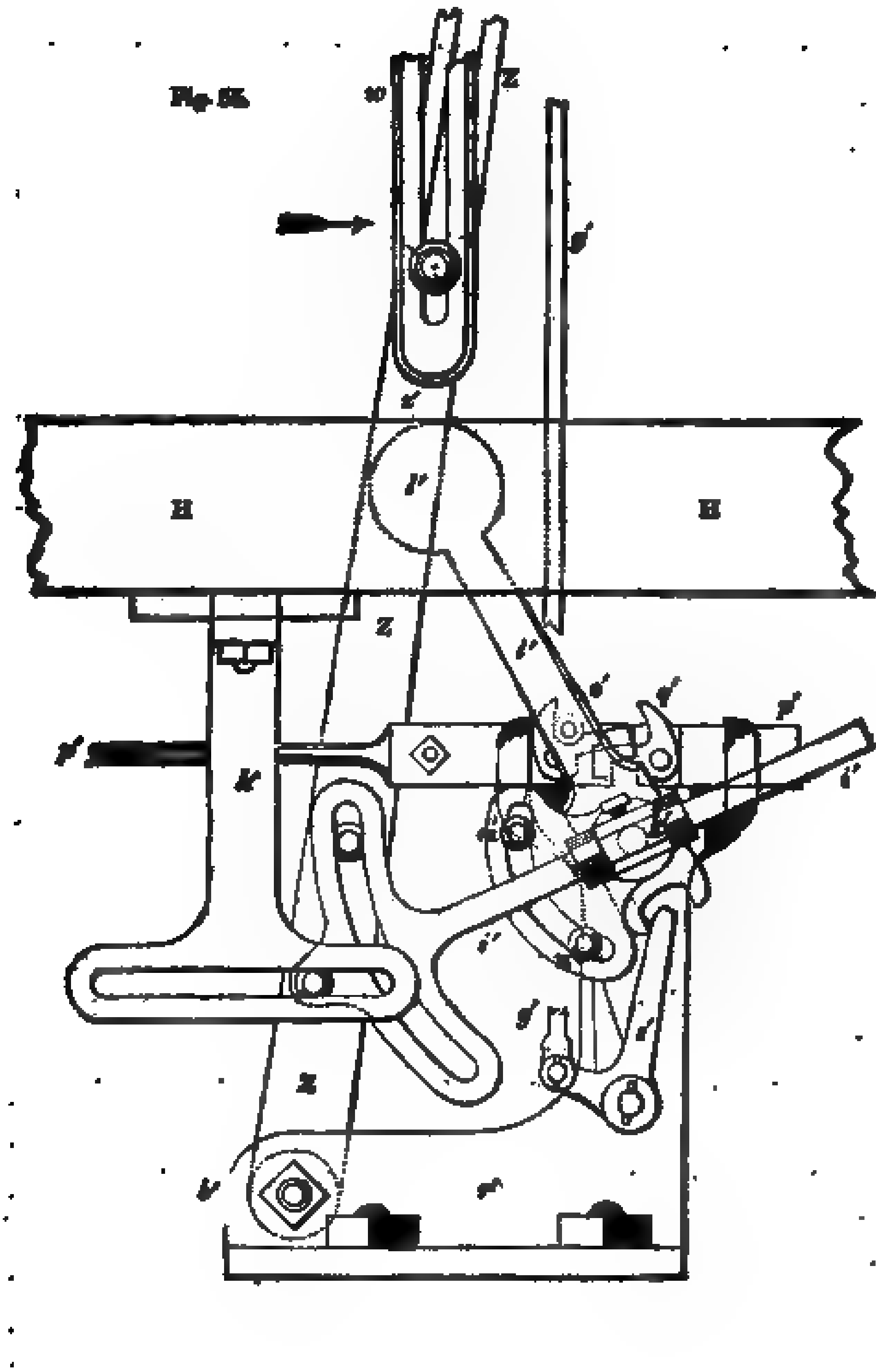


Fig. 54.——Rack-shifting Mechanism of Bobbin-and Fly Frame.
Scale two inches to the foot.

turns loosely upon an axis k'; at the lower end of the lever i' there is a curved slot, in which a stud or pin lies attached to the lever Z; on the centre k' there is a tumbler l', l' furnished with a curved slot-branch, into which are screwed two pins m' and n'. A pin or stud o' screwed into the tumbler l', moves by tumbling (from the right to the left, or from the left to the right,) the rod p', so as to shift one of the bevel wheels 19 or 20, into geer with the wheel 18 (see plate IV.); by which means, as was formerly stated, the up-and-down motion of the copping-rail H is produced. The tumbling of the lever l', loaded with a ball weight at its end, is occasioned by the lever i', which is moved up or down by h', fixed upon the copping-rail H, and presses against one of the pins m' or n'; after having lifted one of them so high that the weight of the lever l' gets into a position beyond its centre of gravity, (or line of direction,) it will tumble suddenly over. The pin o' will thus strike against one of the catches q' attached to the rod p', and lifting it from a projection upon the frame-piece r', will finally move the rod p', either in the one direction or the other.

By the tumbling of the lever l', its other end will also move the upright arm of the bell-crank s'; to the horizontal branch of which the rod g' is joined, which disengages by the jerk of the tumbler, one of the clicks, or detents, x or y' plate IV. This escapement permits the slide-piece v to advance one tooth, and also to move the lever Z a little to the left, or in the direction of the arrow. This movement also makes the lever i', fig. 55, 56, to slide a little backwards through the staple-boss at k', by means of the

pin upon the lever z', by which i' is guided in its slot, when moving up and down, in consequence of its connexion with the piece h', and the copping-rail H. The lever i', therefore, after one going up and down (vertical traverse, or ascent and descent) of the bobbins comes to strike every time sooner and sooner against one of the pins m' and n', fixed in the small curved slot of adjustment of the lever l', and thus shortens the extent or range of that motion, while also its velocity is decreased by the sliding of the strap from the smaller to the larger end of the cone, as was formerly explained.

It remains now to show only how the bobbins may be always filled to the same degree at each repetition of the movement, by the machine putting itself out of geer, at the definite period deemed proper for the spinner's purpose. To the rack-piece v is attached a pin t', which, when the rack has arrived at the end of its course, strikes up the catch u', by which the bell-crank lever v', carrying the pulley e', and the suspended weight f', is permitted to obey the action of this weight, and thus move the geering-rod M, so as to throw the driving-strap from the steam-pulley, upon the loose one alongside of it.

The full bobbins being now removed, and replaced by empty ones, the roving-tenter (usually a female) brings back the rack v to its primitive position by the traction of the rope w', which is wound up by a winch-handle upon a small barrel x', whose axis turns in the roller-beam E. Before the tenter works this handle, she raises the end bearing y' of the cone P, by a lever on which it rests, thus permitting the strap of the pulley O to slide easily to the smaller end of

the cone, while the rack is pulled back by the rope. The bearing at the thick end of the cone z' turns upon a stud fulcrum, so as to allow the thin end to be readily lifted a little way by the hand of the operative.

In fig. 49, p. 63, one of the roving spindles is represented, along with the bobbin and its driving wheels. The modern mechanism is likewise shown for laying on the roving in a compressed state, which can be used only in the frames adapted to make conical-shaped rovings (such as we have just described). Upon the end of the tube-arm of the flyer there is a brass ring a'', with a brass finger b'', resting upon the roving of the bobbin, and pressing by means of a spring c'', which works or re-acts against the shoulder d'' of the ring. In the flattened point of the finger there is a slit through which the roving passes in its way to the bobbin, meanwhile revolving and gliding up and down under regulated pressure. By giving the roving a turn (as shown in the figure) round the finger, it is prevented from being thrown out and unduly stretched by the centrifugal force generated by the rotation of the flyer.

In plate IV., a few spindles of the back range are shown to complete our explanation of this seemingly complex but perfect automaton. One spindle is left naked, two are exhibited with the bobbins empty, and one with a full bobbin. The spindles of the front range F'' were broken over near the bottom, to keep the drawing neat and perspicuous.

Fig. 57 represents, in a plan, or horizontal section, the copping-rail H, with its two alternate rows of spindles viewed from above; three spindles being

shown as mounted with their flyers and bobbins, and three others without them, in order to exhibit the driving shafts and wheels.

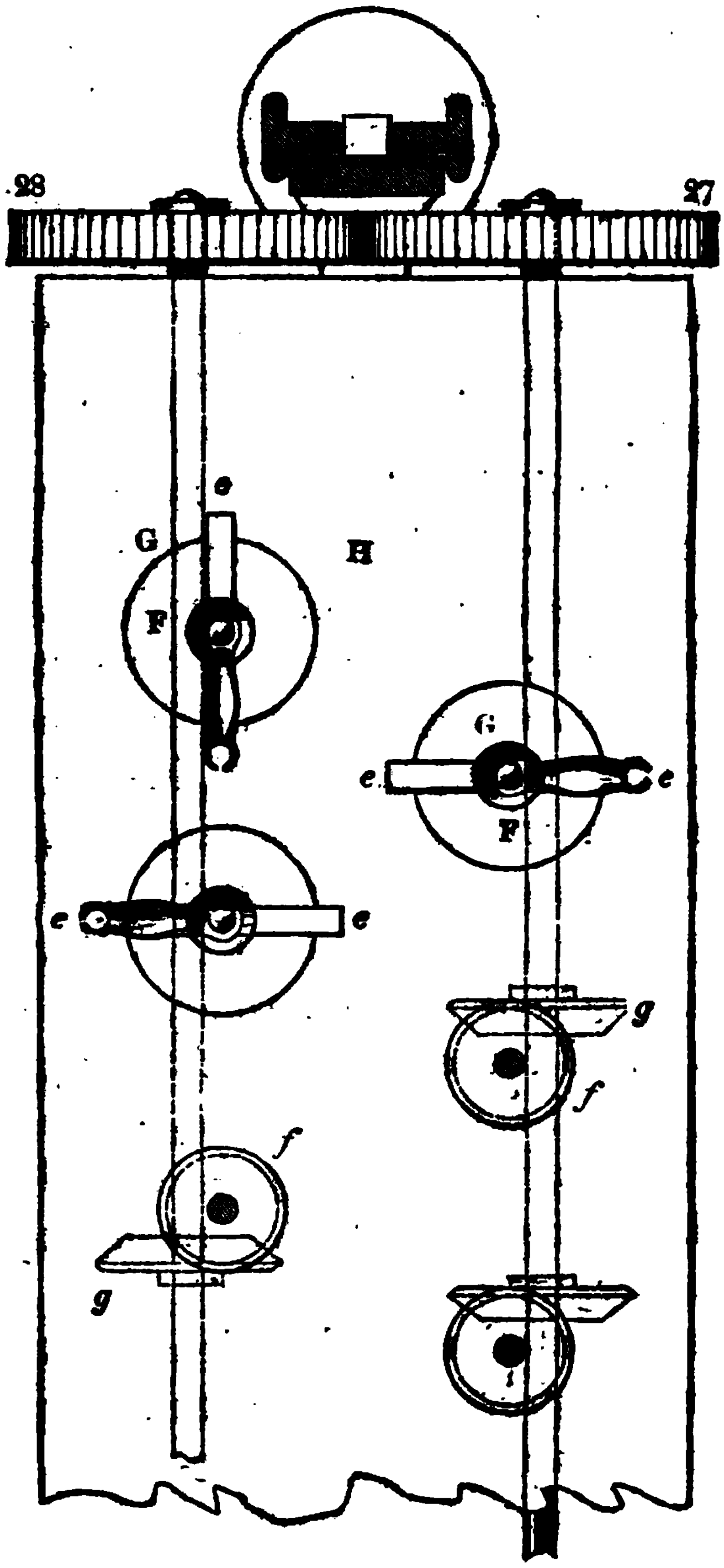


Fig. 57.—Ground Plan of Spindles and their Drawing Wheels, in the Bobbin-and-Fly Frame. Scale two inches to the foot.

Fig. 58 is a back view of one end of the bobbin-and-fly frame of Messrs. Cocker and Higgins, with Mr. Houldsworth's differential box, but without the bevel wheel movements of the spindles and bobbins. Machines of this kind are now doing good work in a great many cotton-mills, and they therefore merit an explanation, were it for nothing else than to illustrate the rapid march of improvement in factory invention. It is adapted to the bobbins with disc ends, which are filled with a soft coil of roving in a cylindrical form. Fig. 59 is a cross section, showing merely some of the principal parts.

This fly-frame differs from the most recent (above described) in the following respects:—1, In wanting the tumbling apparatus U, for reversing the motions of the copping-rail; that motion being here produced by a uniformly revolving motion of the shaft S, working by the pinion 21, upon its end, in the teeth of a mangle-wheel, in which it shifts alternately from the outside to the inside, for reversing the direction of the movements. These, however, continue of equal extent as the roving here is laid on evenly from end to end of the bobbin. In the absence of the apparatus U, the rod *g′*, which raises alternately one of the clicks *x* and *y*, is disengaged with a jerk, directly from the copping-rail, the instant it arrives at the top and bottom of its course.

All the other motions and actions are the same in this and in the previously-described bobbin-and-fly frame, except that the flyers are not mounted with spring pressers, as the wooden ends of the bobbins would interfere with their operation. This is certainly a great disadvantage; since a bobbin mounted with a presser can

Fig. 56.—Bobbin-and- Frame, with the Mangle-wheel movement.
Scale, one inch to the foot.

take on a great deal more roving at a time, and need, therefore, to be far less frequently changed in the creel, either of the fine bobbin-and-fly frame, the mule, or the throstle. I made the following experiments at Mr. Orrell's factory, on uncompressed and compressed bobbins:—

	Ounces.
The large bobbin of the first, or coarse bobbin-and-fly frame, contained of roving applied by the spring presser	14
The same sized bobbin filled with uncompressed rovings, only	7½
The smaller bobbins of the second, or fine bobbin-and-fly frame, contained of compressed roving	8
The same sized bobbin, uncompressed . .	2½

These numbers are the means of several weighings.

2,400 inches, or 200 feet, of the fine roving weighed 160 grains. It was perfectly uniform in texture; the motion of the large spindles in his frames being so true and easy, as to be undiscernible by the eye. It was necessary to touch them, in order to ascertain whether they were moving or at rest.

It is a principle universally recognised at the present day, especially for fine spinning, that the less twist rovings receive the better yarn will they, *ceteris paribus*, furnish.

The spindles in the above coarse roving-frame turn 750 times in a minute, for 100 revolutions of the front roller, whose diameter is 1¼ inch. As its periphery is therefore very nearly 4 inches, that frame will turn off for each spindle $4 \times 100 = 400$ inches per minute $= 24,000$ inches, or 666⅔ yards per hour.

In the fine bobbin-and-fly frame, the spindles move with the same velocity, but the front roller makes only 80 revolutions in the minute; hence more twisting power is here employed in the proportion of 100 to 80, and the quantity given off in one hour will be about $4 \times 80 \times 60 = 19{,}200$ inches $= 1600$ feet, or $533\frac{1}{3}$ yards.

A conical bobbin, with compressed roving from the fine bobbin-and-fly frame, will last in a mule five days, and in a throstle six, which is three times longer than the uncompressed bobbins do.

Coarse roving is often called slubbing.

The advantage of the improved bobbin-and-fly frame, as above described, may be judged of from the following fact, which I learned from good authority at Manchester. In an excellent fine spinning-mill, the revolving can-frame was long used, in conjunction with the stretcher mule, to make fine rovings. Of late years, since the first and second bobbin-and-fly frames have been introduced into this factory instead of the can-frame, three bobbin-and-fly frames with one stretcher mule do for 7*l.* what formerly cost 16*l.*

In the coarse bobbin-and-fly frame the sliver is doubled, by setting two cans with drawings in connexion with one portion of the fluted roller. In the fine bobbin-and-fly frame, there is no doubling of the roving. To two sets of drawing-frames, two coarse bobbin-and-fly frames, and four fine ones are usually assigned. Fourteen cards will be equivalent to the whole—to constitute two *preparations*.

In the bobbin-and-fly frame, the sliver is elongated about from four to six times; the principal draught of $4\frac{1}{2}$ being between the front and middle rollers, and

the remaining 1½ between the middle and back rollers.

The mangle-wheel, for reversing the motion of the copping-rail, was introduced by Mr. Kennedy many years ago into the bobbin-and-fly frames; but the conical form of the bobbin is found so favourable to fine work, as now to cause a preference to be given to the bevel wheel and tumbler plan of reversing the said motions.

Messrs. Cocker and Higgins informed me, that they contrived and executed the first bobbin-and-fly frames about the year 1815, and introduced into it the differential motions of the cone, and the unequal toothed rack escapement with shifting clicks—an invention which did the greatest honour to their mechanical ingenuity and judgment, and established their reputation as factory machinists all over the world. The teeth of their rack required to be cut by a particular machine, conformably to the segments of a parabolic curve.

Mr. Houldsworth's rack, with *equal* teeth, has superseded all these calculations and adjustments of the old rack. It will suit rovings which differ even 100 per cent. in thickness, that is, from 30 to 60 coils, without changing the rack.

The coarse bobbin-and-fly frame has 30 spindles.
The fine do. do. 60 do.;
but I have seen a double one in Manchester with 120; and Messrs. André Kœchlin and Co., of Mulhouse, have constructed a great many of the same size, with a somewhat modified construction, in which the spindles and bobbins are driven by oblique toothed wheels and snail-work, instead of conical bevel wheels.

For fine spinning, the double-conical rovings are weighed on the bobbins by a quadrant beam, and distributed according to their respective weights into five numbered baskets; such nicety is required for the best quality of work. In some coarse spinning-mills, only one carding, one drawing, and one roving are employed for the manufacture of inferior calicoes at the cheapest rate.

In the coarse bobbin-and-fly frame, it is usual to make the spindle go quicker than the bobbin, and in the fine to make it go slower, by which the winding goes on backwards. Let us state a case in numbers for the sake of illustration. If 45 inches of roving are to be wound upon a bobbin whose barrel is 4½ inches in circumference, 10 turns will be required. Suppose that these 45 inches should receive 30 turns of twist, the spindle, and consequently its attached flyer, must give these 30 turns during the winding on of the roving. If the bobbin therefore is 1½ inch in diameter, it must make 10 turns for the winding on, and 30 turns in following the spindle; in all 40 revolutions.

If the bobbin be 3 inches in diameter, or 9 in circumference, it must make only 5 turns to wind on the 45 inches; these 5 turns added to the 30 turns required for twist, make 35 revolutions; and thus for any other dimensions of the bobbin. It hence results, that the number of turns of the bobbin, *plus* the number of turns of the spindle, is a quantity always inversely as the diameter of the bobbin.

The motion of the bobbin and spindle is simultaneous and in the same direction, with a difference varying more or less according to the variable diameter of the bobbins. But to render the matter still plainer,

suppose for a moment the spindle to be stationary; then the bobbin must turn with such a velocity, that it shall wind on the roving just as fast as the front rollers deliver it. This roving comes forward at a uniform rate; but the bobbin growing continually larger in diameter should turn with a velocity uniformly retarded. Let us now restore motion to the spindle: it is evident that when the winding is forwards, as in the fine fly-frame, we must deduct from the rotation of the bobbin, needed for winding on the roving, that of the spindle required for the twist; for the circumference of the bobbin being 4½ inches, 10 turns take up 45 inches. These 10 turns deducted from the 30 made by the spindle, leave only 20 turns for the effective speed of the bobbin; or, if the circumference be 9 inches, 5 turns will take up the 45 inches, if the spindle be at rest; but if the spindle makes 30 turns for twist, the effective speed of the bobbin will be $30 - 5 = 25$ turns. Hence for the fine bobbin-and-fly frame we find that the number of turns of the spindle, *minus* the number of turns made by the bobbin in the same time, is a quantity inversely as the diameter of the bobbin.

In the coarse frame, the bobbin should move faster than the spindle, and its speed should go on diminishing; while in the fine frame, the speed of the bobbin is less than that of the spindle, and it goes on progressively increasing. For this reason the cones of these two machines are set in opposite directions. This arrangement is not, however, indispensable, for the cone might be placed similarly in each; but as the fine frame has a good deal of twisting to perform, the bobbin would need to turn still more rapidly than

in the coarse frame, which would consume more moving force, for which reason it has been found more advantageous to make it revolve in the opposite direction.

It has been stated that the twist of the roving in the fine fly-frame takes place in an opposite direction to that in the coarse one; this is a practice with spinners of which it would be difficult to ascertain the origin or to assign the cause. To do and undo is no part of the economy of manufactures.

It may probably be agreeable to some of my readers, and may help their comprehension of Mr. H. Houldsworth's invention, to be presented with an abstract of its description, as given in the specification of his patent.

The main shaft of the machine C (see fig. 52, and plate IV.), turned by a band and rigger (strap and pulley) as usual, communicates motion by a train of wheels through a shaft to the drawing-rollers at the reverse end of the machine, and causes them to deliver the filaments to be twisted. Upon this main shaft C, is mounted a cylindrical hollow box or drum-pulley, from whence one cord passes to drive the whirls and spindles, and another to drive the bobbins (this is now done by wheel-work).

This cylindrical box-pulley (figs. 52, 53, 54) is made in two parts, *k* and *l*, and slipped on to the axle with a toothed-wheel *o*, intervening between them. That portion of the box with its pulley marked *l*, fig. 52, is fixed to the shaft C; but the other part of the box and its pulley *k*, and the toothed-wheel *o*, slide loosely round upon the shaft C; and when brought in contact and confined by a fixed collar or keyed-

wedge *n*, they constitute two distinct pulleys, one being intended to actuate the spindles, and the other the bobbins.

In the web (plane) of the wheel *o*, a small bevel pinion *p* is mounted upon an axle, standing at right angles to the shaft C, which pinion is intended to take into the two bevel pinions *q* and *r*, respectively fixed upon bosses, embracing the shaft in the interior of the boxes *k* and *l*. Now, it being remembered that the pinion *r* and its box *l* are fixed to the shaft C, and turn with it, if the loose wheel *o* be independently turned upon the shaft with a different velocity, its pinion *p* taking into *r* will be made to revolve upon its axle, and to drive the pinion *r*, and pulley-box *k*, in the same direction as the wheel *o*; and this rotatory movement of the box *k* and wheel *o* may be faster or slower than the shaft C and box *l*, according to the velocity with which the wheel *o* is turned.

Having explained the construction of the box-pulleys *k* and *l*, which are the particular features of novelty claimed under this patent, their office and advantage will be seen by describing the general movements of the machine.

The main shaft C being turned by the band and rigger as above said, the train of wheels *m* (1, 2, 3, plate IV.) connected to it actuates the whole series of drawing-rollers. Upon the shaft N, there is a sliding pulley *o*, carrying a band which passes to a tension pulley *n*, and is kept distended by a weight. This band in its descent comes in contact with the surface of the cone P, and causes the cone to revolve by the friction of the band running against it. The pulley *o* is progressively slidden along the shaft N, by means

of the rack and weight, which movement of the pulley is for the purpose of shifting the band progressively from the smaller to the larger diameter of the cone, in order that the speed of its rotation may gradually diminish as the bobbins fill by the winding on of the yarns (rovings).

Connected with the axle of the cone P, a small pinion, 23, is fixed, which takes into the teeth of the loose wheel *o*, and as the cone turns, drives the wheel *o* round upon the shaft C, with a speed dependent always upon the rapidity of the rotation of the cone. Now the box-pulley *k*, (fig. 52) being fixed to the main shaft C, turns with one uniform speed, and, by wheel-work connecting it with the whirls, it drives all the spindles and flyers, which twist the yarn with one continued uniform velocity; but the box-pulley *l*, being loose upon the shaft, and actuated by the bevel pinions within, as described, is made to revolve by the rotation of the wheel *o*, independently of the shaft, and with a different speed from the pulley-box, *k*; and wheels connecting this pulley-box *l* with the bobbins communicate the motion, whatever it may be, of the pulley-box *l* to the bobbins, and cause them to turn, and to take up or wind the yarn with a speed derived from this source, independent of, and differing from, the speed of the spindles and flyers which twist the yarn.

It will be now perceived that these parts being all adjusted to accommodate the taking up movements to the twisting or spinning of any particular quality of yarn intended to be produced, any variations between the velocities of the spinning and taking up, which another quality of yarn may require, may easily be effected, by merely changing the pinion 23, fig. 58, for

one with a different number of teeth, which will cause the wheel o and the pulley-box l to drive the bobbins faster or slower, as would be required in winding on fine or coarse yarn, the speed of the twisting or spinning being the same.

This desirable object is effected in its most simple way by the mechanism above described, and which is extremely simple when considered abstractedly from the ordinary movements of the spinning machine.

There are, however, other modes of effecting the object upon the same principles.

*Popular Explanation of the Mechanism of the Bobbin-and-Fly, (plate IV.) by H. Houldsworth, jun., Esq.**

Upon a shaft N, which lies behind the roller-beam, and is connected by wheel-work with the front roller, there is a sliding fork. This fork has between its prongs a pulley O, which slides with it along the shaft, but the shaft has a groove cut in it lengthwise, and a key or feathered edge in the pulley takes into this groove, so that the shaft cannot turn round without taking the pulley with it. The weight f' tends to draw the pulley towards it; the rod d' is connected with a rack-scapement, which allows the pulley to slide one tooth for each layer wound upon the bobbin. The pulley O drives the cone, and the tightening pulley n lies with its weight upon the strap so as to take up its slack when the strap is working upon the small end of the cone. X is an arm joined to the slide at the one end for carrying at the other the stud on which the pulley n revolves.

The guide-rod slot-plate u u is fixed to the back of the roller-beam, leaving a space of about one inch;

* A written communication.

v is a plate, which slides along the guide-plate. The tail w, of this slide-plate has a slit or slot in it to receive the stud a', which takes into a hole in the lever Z, which works upon the centre b', and has a rod d', at its top end connected with the sliding fork, X O, already described. The vertical bar g' has two pins upon its upper end to lift the catches or detents; the lower part of it is a round rod with two set collars upon it, where it passes through an arm or branch m' n', of the copping-rail.

The action is as follows:—at starting, the sliding-fork X, and pulley, with the rack and lever, are all moved by sliding to the right-hand end of the frame. The weight f', at the left-hand extremity of the frame, tends to pull the whole of the said sliding apparatus towards itself by the traction it impresses on the rod, d'; but it is obstructed by one or other of the catches or detents x, y. When the copping-rail reaches the top of its course, the arm m' n' comes against the top set-collar of the upright bar g', raises it, by which the top catch x, is lifted, and the rack, lever, sliding-fork, pulley, and strap, all shift towards the weight, till the under catch stops the motion by falling into the next tooth of the under rack. When the copping-rail reaches the bottom of its course, its branch comes into contact with the lower set-collar, and makes the bar g' descend so as to pull down the lower catch y, whereby the rack apparatus is allowed to shift another step to the left, till arrested by the upper catch x falling into another tooth of the upper rack, and thus, step by step, the above train of apparatus hitches on towards the left end of the machine. The long bar-lever, Z, has the following use: the cone-strap always

traverses the same distance in filling a bobbin, because the diameters of the empty and full bobbins have a constant difference; as, for instance, 1 or 1¼ inches when empty, and 3 when full, whatever be the fineness of the roving wound upon them. The finer the roving, however, the more coils or layers of it will be required to fill the bobbin, consequently more traverses of the copping-rail, and more escapement motions in the rack; hence a change of rack would apparently be needed for every change of fineness in the roving, but this change is superseded by the intervention of the lever-bar Z. The lever, being attached at c' to the rod d', is thus enabled to act upon it, and thereby to move the sliding-fork upon N. The quantity of this motion is regulated according to the place of the stud a' in the slot branch w. The higher the stud a' is placed in the said slot, the more teeth of the rack will be required to give to the top end of the lever Z the same quantity of strap-traverse motion upon the cone. Suppose, for the sake of illustration, every tooth of the rack to be half an inch; then if the stud is in the middle of the lever-bar Z, the upper end will move one inch for each tooth. The rack has, of course, more teeth than it is ever likely to require for any extent of adjustment, so that by raising the stud, the number of escapements required to cause the conestrap to traverse, may be reduced in any desired degree.*

* The bar Z is a lever of the third kind, in which the fulcrum is at the under end b', the weight to be overcome is at the other end c', and the power or impulse of the arm w, is between them. The motion of that arm is as the size of the teeth of the rack, being one tooth at a time, and it will give more motion to the end c', the nearer the power a' is to the fulcrum or centre of motion b': when applied in

Description of the Tube roving-Frame.

The next machine, in point of importance and mechanical ingenuity, in a cotton-mill, is Danforth's tube-roving frame, which commonly goes by the name of Dyer's, because this gentleman became proprietor of the patent for this invention soon after it was imported from the United States, and has had the merit of bringing it into complete practical operation in the factories of England, and of other countries.

The condensation of the roving delivered by the front rollers is, in this apparatus, elegantly performed by revolving tubes, through which it is made to pass in its way to the bobbins or spools. It is wound upon bobbins which consist of mere wooden tubes, without ends, put upon iron axes, which revolve by the friction of horizontal iron drums or rollers on which the bobbins bear by their own weight, whilst the feeding tube has a traverse movement to distribute the roving along the surface of the bobbin. This traverse movement is progressively shortened, as the diameter of the bobbin is enlarged, in order to generate conical ends, as in the newest bobbin-and-fly frame. The tube-frame contains a drawing-roller beam of the same construction and use as that described in the two preceding machines.

Fig. 60 shows the one end, and fig. 61 the other. In the latter figure, the three pairs of rollers A have been represented in section, and in the other the front one B is shown in an outside view, in order to exhibit their arrangement upon the same roller-beam C, and

the middle of the lever, the range of motion at the end c' will, of course, be doubled; if a' advance one half-inch, c' will describe an arc of one inch.

the same head. With this intent, also, the usual fast and loose pulleys attached to the main-shaft of the frame *a* are merely indicated by dotted lines *b*; the larger pulley *c*, by which the motion is communicated to the revolving tubes, is shown also by dotted lines.

Fig. 62 is a portion of the front view of the machine to explain the working geer, and the manner in which the bobbins are filled.

Fig. 63 is a representation of the essential spinning

Fig. [illegible].—Tube-Roving Frame. View of the one end. Scale, one inch to the foot.

parts of the machine in a section upon a larger scale; and fig. 64 shows the details of some parts subservient to the traverse motion of the tubes.

A and B are, as above stated, two sets of drawing-rollers, into the first of which the slivers are introduced from the cans stationed behind the machine. The roving, after leaving the front rollers of the first set, enters between the back pair of rollers of the second, both sets revolving with the same speed. It is then delivered by the front roller in slender slubbings, which pass across the frame towards the bobbins, ranged in a line in front, and resting upon a number of grooved cylinders D, D, transfixed by a shaft which extends the whole length of the frame. The flutings are cut upon the cylinders in order to create friction against the cotton-covered barrels of the bobbins. E is one of the bobbins filled with roving, lying in its place, with its axis resting between two slots *d, d,* fixed to an iron beam F, made fast like the roller-beam C, between the frame-work, G, of the machine. *See* fig. 62.

e, e, fig. 61, are several arms screwed fast to the roller-beam C, upon the slanting surface of which the bearings *f* may be shifted up and down by pinions *g, g,* working in the racks *h, h.* In these several bearings, the part *f* is for the purpose of sliding a slender iron frame *i,* which is best seen in section (fig. 63). Upon its surface the bearings *l, l,* are fixed, in which the carriers *k, k,* of the revolving tubes may vibrate, or swing upon an axis, as is shown at one point in fig. 62.

m, m, fig. 63, are the tubes revolving with their ends in bushes or holes of their carriers *k.*

n is a guide plate for conducting the roving after it leaves the tube, in passing through which it gets a transient twist.

o is a catch, made fast to the carrier *k*, to suspend it at a rod of iron, which extends the whole length of the machine, when the bobbins are to be changed, whilst at other times it presses with the plate *n*, upon the roving of the bobbin E, as shown by dotted lines in fig. 63.

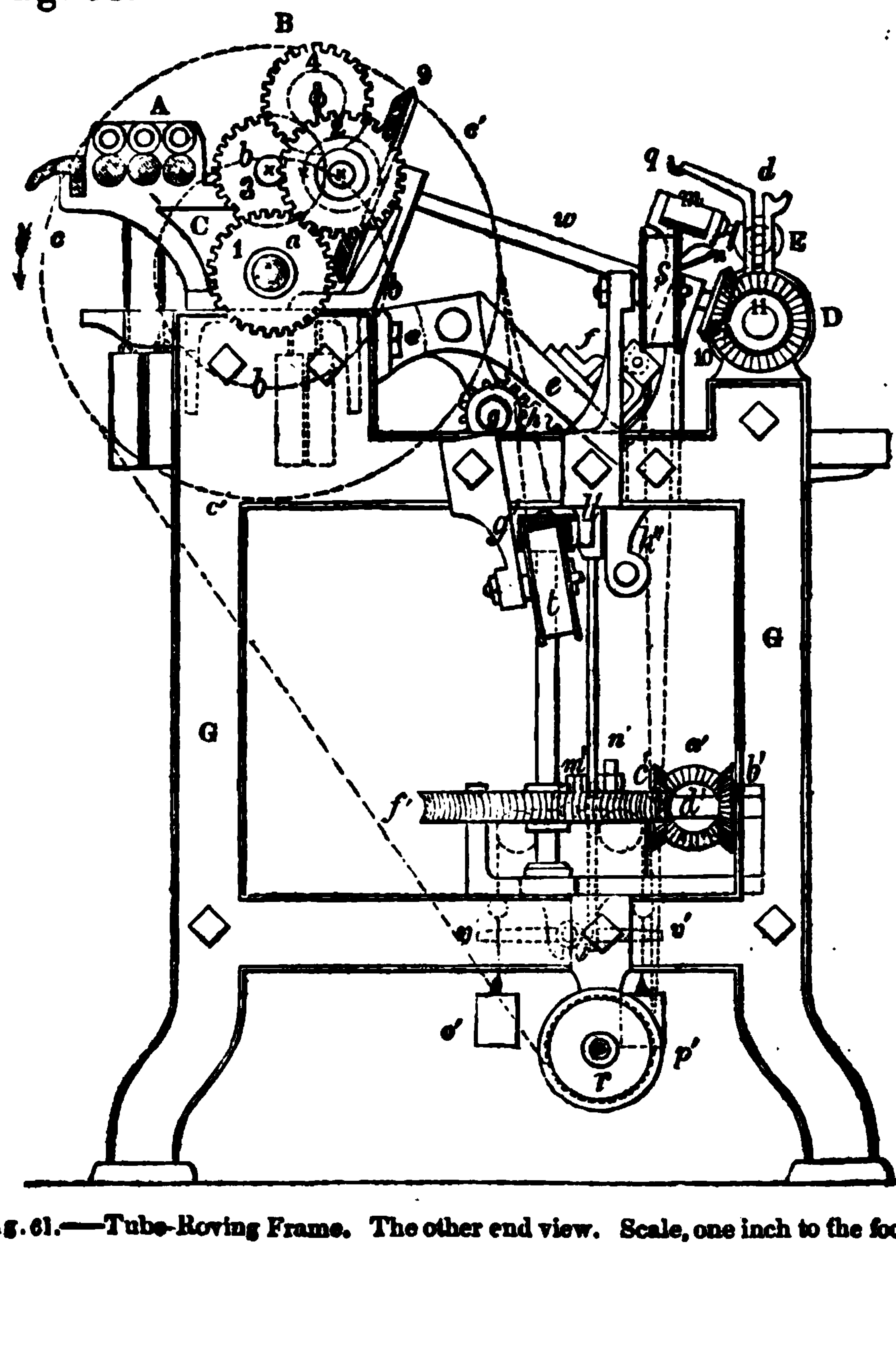


Fig. 61.—Tube-Roving Frame. The other end view. Scale, one inch to the foot.

Whilst the bobbin is filling, the beam *i*, with all the carriers, *k*, *k*, figs. 62, 63, is gradually shifted upwards by the pinions, *g*, working the racks *h*, *h*, of the bearings, *f*, *f*; thus producing, in the same direction, a constant pressure of the delivering ends of the tubes *m*, *m*, against the bobbins E, which being turned by the carrier-rollers D, wind-on the roving as it comes through the hole of the plate *n*. At the same time the beam *i* is sliding or vibrating to and fro, in a line parallel with the ends of the bobbins, so as to distribute the roving properly over their barrels. The extent of this traverse motion is shortened a little at each circuit, in order to form the ends into a conical shape, as with the most improved fly-frame.

When the bobbins are sufficiently filled, the machine is so adjusted as to stop itself, by throwing its driving strap upon the loose pulley. The tube-carriers *k*, *k*, being suspended at the slender rod *p*, the filled bobbins are lifted from the slots *d*, and laid in the notches *q*, for the sake of dispatch, whilst empty bobbins, previously put on their axes, are laid in their places. The same series of operations are once more renewed.

The motions of the tube-roving frame are produced as follows:—

The dotted lines *b*, *b*, (fig. 61) represent, as was said, the steam pulleys in front of that view. The dotted lines *c*, *c*, show another larger pulley upon the same shaft *a*, from which a strap is led over the pulleys *r*, *s*, and *t*, fig. 61, as shown by dotted lines. The strap then passes through the whole length of the machine and over the pulleys *u* and *v* at its other end (see figs. 60 and 62). The strap, in going from the pulley *s* to *u*, passes round the tubes *m*, *m*, in such

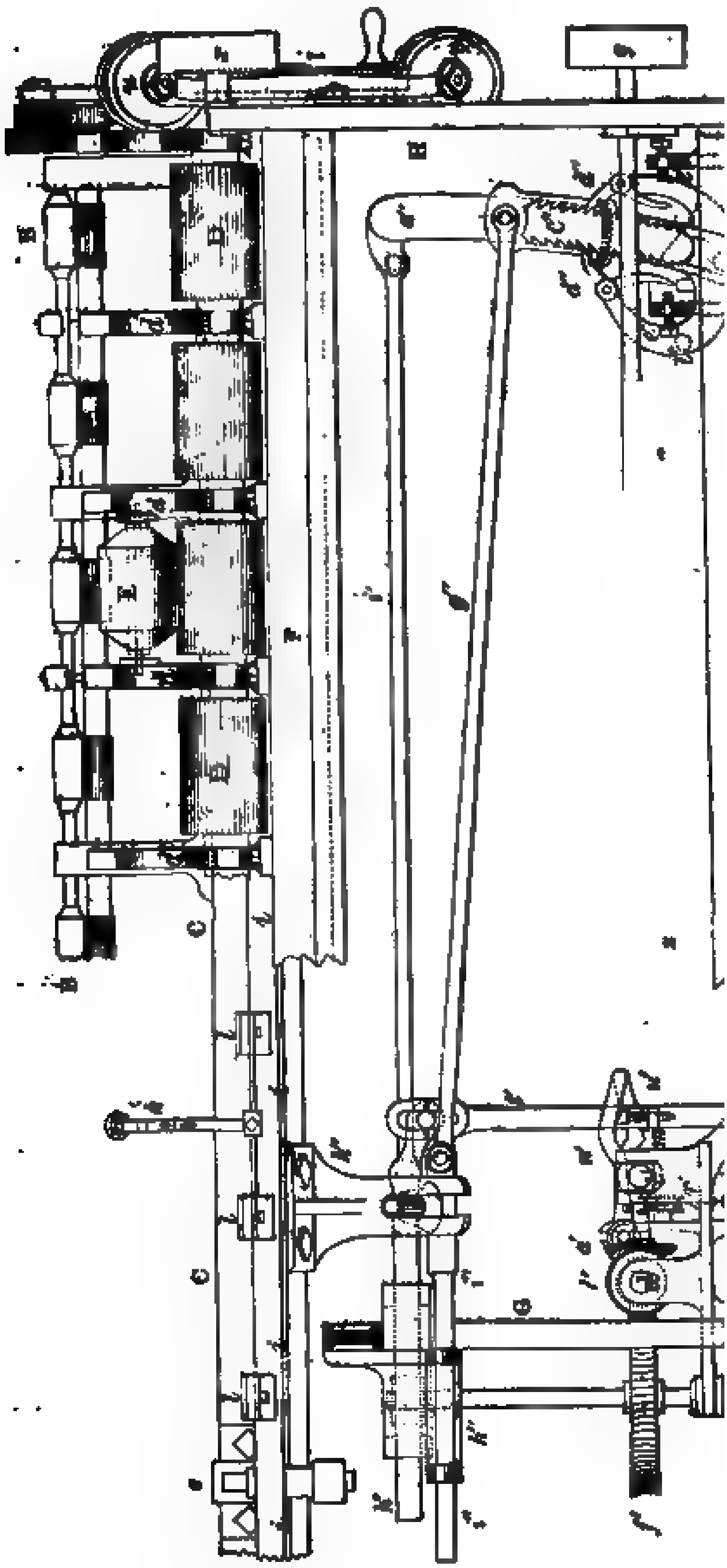


Fig. 40.—Tube-Roving Frame. Front View. Scale one inch to the foot.

a manner as to go in one of the carriers k, fig. 61, over, and in the next under the tubes, which are thus made to revolve by the friction of the strap, without obstructing their traverse motion along with the beam i.

Upon the shaft a is a wheel 1, which drives the front roller of the roller-beam set B by a wheel 2; from that roller, motion is given to the wheel 3 upon the back roller by a small wheel upon the front roller, and two carrier wheels 4. From this back roller, the front roller of the other set A is moved with equal speed by a driving and a carrier wheel (not represented), and which give motion also to the back roller of the set A, in the same manner as explained for the set B. The middle rollers of both sets get their motion at the other end of the frame, fig. 60, by wheels 5 and 6 attached to them and to their respective front rollers, with the aid of two carrier wheels 7 and 8.

Upon the front roller shaft of the set B is a third wheel, a bevel one, behind the wheel 2, fig. 61, which drives the large bevel-wheel 9, and the inclined shaft w, which transmits the motion by two bevel wheels, 10 and 11, to the bobbin roller shaft D.

Upon the other end of this shaft there is a pulley x, whence motion is given by a strap to the pulley y upon the shaft z. This shaft is represented in plan (fig. 64), and works, as there shown, by a bevel wheel a', into either of the two bevel wheels b' and c', giving a motion in a different direction to the shaft d', according as it happens to be shifted into geer with b' or c'. This shifting is effected by moving the bar l' (in which is the and bearing of the shaft z) a little the one way or the other, and keeping it in that position by either of the catches m' or n' falling into notches of the said

bar l'. The bar is moved by one of the two weights o' and p', fig. 61, working with a chain over the pulleys, q' and r', upon a pin or stud s' fixed to the frame, whilst the other weight is suspended. *See* also *fig.* 64.

The two chains of the said weights pass through holes in the end of a balance-beam v', over each of

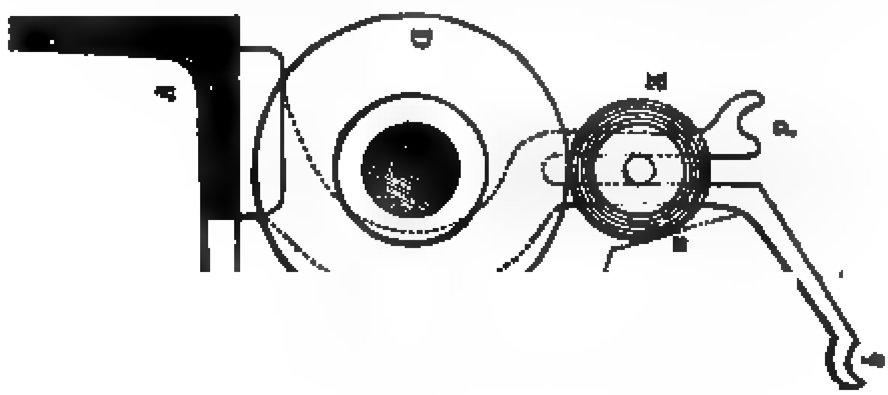


Fig. 62.—Tube-Roving Frame. Working parts in section. Scale three inches to the foot.

which holes there is a little ball upon the chain, against one of which the balance-beam is alternately pressed, in order to suspend that particular weight, whilst one of the catches, *m′* and *n′*, is lifted from the notch in the bar *l′*, letting the bar be drawn by the other weight in the opposite direction, so as to bring the bevel wheel *a′* into geer with the other of the two bevel wheels *b′* and *c′*.

Upon the shaft *d′* there is a worm *e′*, which works in a horizontal wheel *f′*, and drives by means of a little pinion *g′*, and a rack *h′*, figs. 61, 62, and 64. This rack is connected by a rod *i′* with the apparatus H, for shortening the traverse motion of the beam *i*. The rack *h′* is moreover connected with the bell-crank lever *t′*, which has at the sides of its upright branch two screws for lifting alternately the catches *m′* and *n′*, whenever the lever *t′* arrives at one end of its traverse motion.

In fig. 62 may be seen the shape of the catches which enable them to produce this effect. The other end of the bell-crank lever *t′*, raises or depresses one end of the balance-beam *v′*, at the end of each traverse motion, thus stopping the action of one of the weights *o′* and *p′*, whilst the other is drawing the bar *l′*, so that the catch, *m′* or *n′*, which was not previously lifted by the screw *w′*, falls now into its notch, keeping the wheel *a′* in geer, till the crank-lever *t′*, at the other end of its traverse motion, lifts this catch and suspends the other weight. We can thus perceive how the rod *i′* is regularly moved to the right hand and to the left, and we have only now to show how this motion is constantly shortened and communicated to the beam *i*. Fig. 65, *a″* is a curved arm swinging round a

centre, b'', its other end being attached to the rod i', fig. 62. On the arm a'', a serrated plate, or rack c'', slides downwards during the working of the machine. In the teeth of that rack, on each side, a click works, kept in the teeth by a spiral spring, which connects both clicks, d'', d''. When the arm a'', drawn by the rod i', has reached the end of its traverse motion, it presses one of the clicks, d'', d'', against the point of one of the set screws e'', e'', which pushes the click out of

Fig. 64.—Tube-Roving-Frame. Details of the Traverse Motion, shown in plan. Scale, three inches to the foot.

the tooth of the sliding-piece, c'', thus permitting it to fall through the depth of half a tooth, the other click d'' immediately catching it. Whilst, therefore, the point l'' approaches continually to the swinging joint b'', the traverse motion given from that point l'', by a rod g'', to the beam i, must become shorter; the arm a'' swinging through equal spaces. The teeth are cut at alternate intervals on either side of the sliding rack c'', so that the motion at each time is limited to half a tooth. h'' is a staple-guide screwed to one of the middle frames, G', of the machine, to conduct a rod i'', connected with the rod g', and which is joined (fig. 62,) to a slot arm k'', fixed to the beam i, on which the tube carriers stand, as previously described. At each traverse of the rack-guide a'', a pin l'', figs. 62 and 76, projecting from the curved piece near the bottom of the said rack-guide, strikes against a lever m'', seen with its end in fig. 60, and by moving the lever n'', moves the ratchet wheel I, fixed upon the same shaft with the pinion g, through one tooth by means of the click o'', whilst another click p'' prevents the ratchet wheel from running back in consequence of the weight of the beam i'', which gradually rises as the bobbins grow larger. When the rack c'' has descended to its lowest point, a projection q'' comes to press upon the end of a lever m'', which at its other end disengages a catch seen in dotted lines s'' (figs. 60 and 65), and which makes the upright lever t'' move the horizontal rod u'' (which extends the whole length of the machine) bearing upon its other end the fork for throwing the strap from the fixed to the loose pulley. The lever t'' is acted upon by a slight weight which tends to move it round upon its fulcrum r'', and to push the rod u''

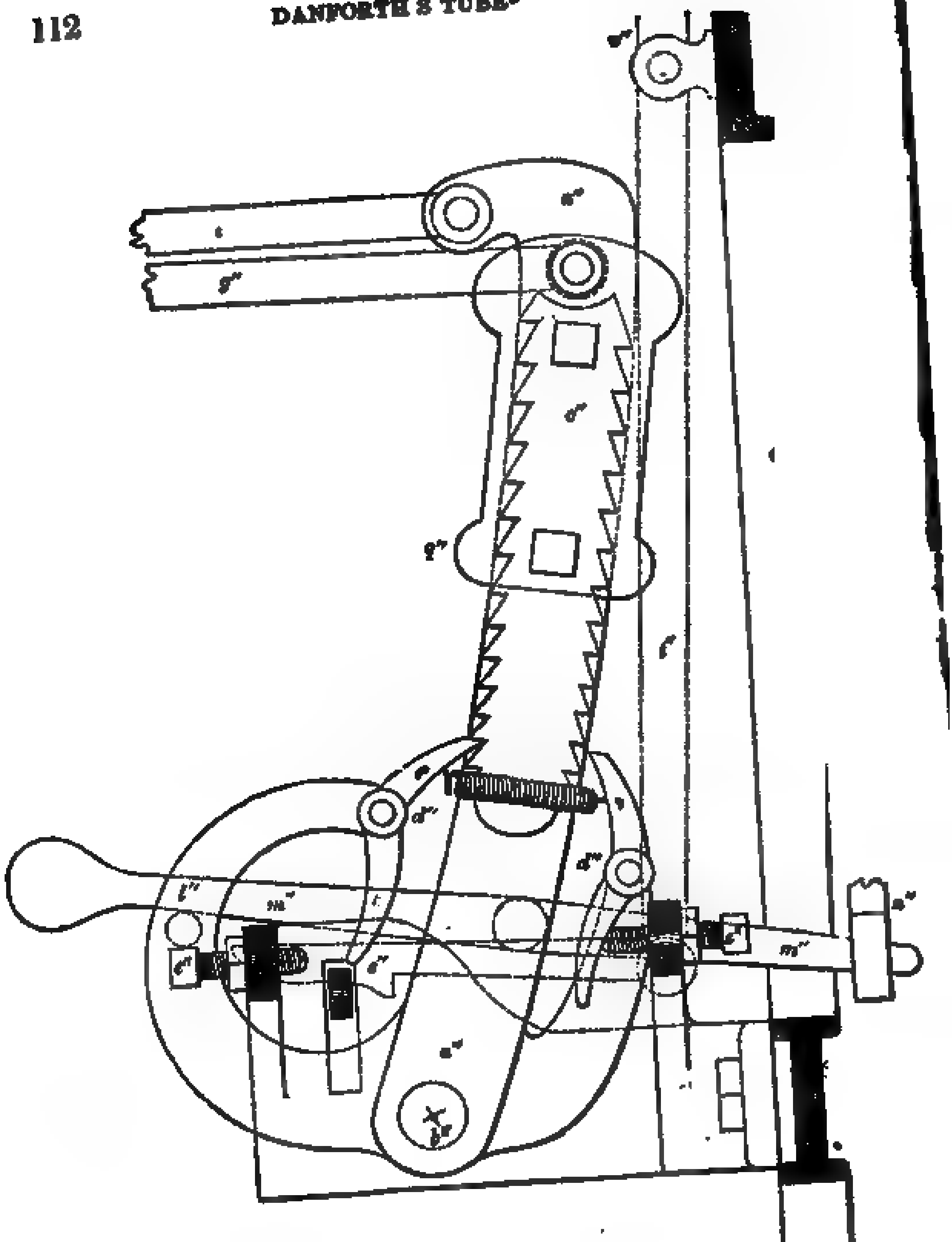


Fig. [illegible].—Tube-Roving Frame. Details of the Traverse Motion of the Tubes. Scale, three inches to the foot.

horizontally. This rod serves also to enable the attendant to throw the machine in or out of geer, at whatever end he may happen to be, by seizing it in his hand, and sliding it along.

The tube-roving frame is a most expeditious machine, and is employed with great advantage in many coarse spinning-mills for numbers under 30's.; but it is still a subject of considerable debate between respectable spinners whether it can be profitably employed for preparing the rovings of finer yarns.

Its front rollers move from three to four times faster than those of the bobbin-and-fly frame; hence 16 tubes of the former frame will turn off quite as much slab as 60 spindles of the latter, and are reckoned equivalent to them in their first cost, bulk, and power of working.

At one cotton mill in Manchester where the tube-frame is a favourite with the manager, each bobbin or spool takes on two hanks, weighing from six to seven ounces, in obedience to the pressure plan. The roving has five hanks to the pound, which is pretty fine. At this establishment the front rollers turn 450 times in the minute; in another which I visited, 470 times.

A skilful cotton spinner assured me that in his hands he found the tube-machine liable to many accidents, for if a particle of dirt or seed remains in the cotton after the carding and drawing, it will prevent the delivery of the roving upon the bobbin in the untwisted state peculiar to this machine, and will leave points of torsion which create incorrigible defects in the yarn spun from it; hence, said he, it cannot be used for fustian yarns, which must be very level. It is very suitable, however, he added, for a factory of low-priced calicoes. The capricious nature of cotton-

spinning is shown by nothing more strikingly than by the fact of this gentleman having tried in vain to work rovings for 20's with the tube-frame, though his brother and partner, with similar cotton, similarly treated, succeeded perfectly well in producing good yarns of that count by means of this roving frame.

Another manufacturer, who has a high character for skill in spinning, assured me that yarns spun with the aid of the tube frame were too unequal for weaving into cloth for good calico-printing. There can be no doubt, however, from what I saw in many well-conducted mills, that under proper management the tube roving frame is a very excellent and profitable machine.

The first patent for this apparatus was obtained in this country by Joseph Cheeseborough Dyer, Esq., of Manchester, in July, 1825, as an invention communicated to him by a foreigner residing abroad. The following extract from his specification will serve to complete our account of this interesting machine:—

By the rapid rotation of the spindles (tubes), the rovings are twisted from the spindles backwards as far as the delivering drawing-rollers, which twisting is for the purpose of giving strength to the rovings, that is, tenacity to the fibres of the cotton, but as soon as the rovings have passed the eccentric part of the tube, the twist will be immediately discharged, and the rovings wound upon the spools or bobbins in an untwisted state.

The rotation of the drawing rollers which deliver the rovings being uniform, it is necessary to regulate the speed of the taking up or winding of the rovings on to the bobbins or spools, according to their increased diameters. This regulation of the speed, the machine

effects without assistance, the bobbins being turned by the friction of contact between their surfaces and those of the carrier cylinders, by which it will be perceived that however much the diameter of the bobbin may increase by the repeated thicknesses of roving wound upon it, only a given extent of its surface will be carried round at every revolution of the carrier-cylinder, and hence the quantity of roving taken up in any given space of time, will be uniform throughout the winding.

Mr. Dyer has made many important improvements upon his machine since the above date, for which he has likewise obtained patents. The engravings here given are taken from drawings most carefully executed under my inspection from a machine newly constructed, and in the very act of being set to work, in a mill at Manchester.

The rovings of the tube-frame are entirely destitute of twist, the twist communicated by the rotation of the tubes being only momentary, for the purpose of giving cohesion to the filaments in their way to be wound upon the bobbins. As the sliver is pinched at the one end between the delivering rollers, and at the other by the nozzle of the tube pressing upon the bobbins, it is obvious that the middle portion of it can receive no permanent twist; what it receives *in transitu* is undone in the act of winding-on.

CHAP. IV.

Finishing Processes of a Cotton-Mill.

SECTION I.—Stretching Mule.

After passing the cotton through one or two bobbin-and-fly frames, or the tube frame, according to the quality of yarn intended to be produced, the rovings are pieced up to the mule or throstle, and spun into yarn. In the finer branches of the trade, however, there is an intermediate process called stretching, in which the rovings are made finer or more attenuated than can be done advantageously on the bobbin-and-fly frames. The machine employed for this purpose is called a stretching frame, and differs essentially from the bobbin-and-fly frame in the mode of twisting and winding on. In the latter, the roving is made and wound up simultaneously, but in the stretching-frame a length of roving is first spun, generally fifty-four inches long, and then the motions of the rollers and spindles are suspended while the winding-up is effected. The stretching-frame is, in fact, a mule-jenny, without the second draught and second speed. The action of the machine may be briefly described as follows—reserving the complete description of the mule for Section III. The bobbins filled at the previous operation being placed upon skewers in the creel, the loose ends of the rovings are introduced between the top and bottom back roller, and are passed forward through the other two rollers, so as to be delivered in front in an elongated and consequently attenuated

state, proportional to the draught—that is, to the relative speed of the back and front rollers. The ends of the rovings, being thus elongated, are severally attached to a spindle fixed in the carriage. When the machine starts, the roving is given out by the front rollers, and the carriage is made to recede from them at a speed equal to the rate at which the roving is given out, by which means the roving, as it issues from the front rollers, is kept extended between the spindles and rollers. While the carriage is coming out, the rovings are twisted by the revolution of the spindles, and when it has advanced about fifty-four inches, it stops, as well as the rollers. The twist is produced without the aid of the flyer (of the fly-frame) by the rovings being coiled diagonally up to the point of the spindle, where, from the inclined position of the latter towards the rollers, the one end of the roving remains during the revolution of the spindle, and twists with its twirling. When the carriage stops, the spindle stops also. It is then the business of the attendant to wind up the fifty-four inches of roving thus made, which she does by depressing the faller wire with her left hand, so as to bring the rovings at right angles to their respective spindles. She then turns the spindles round by means of the handle, with her right hand, while she pushes the carriage in towards the roller beam at the exact velocity with which the thread is to be wound up —a task of great delicacy, owing to the very soft state of the fine slab. As the carriage gets near the roller-beam, she slowly raises the faller wire during the last turn of the spindle, and then the roving, from the relative position of the spindle and roller, again coils itself diagonally up to the point of the spindle, ready to recom-

mence the twisting of another length of elongated roving. This immediately takes place by the simultaneous movement of the rollers, the spindle, and the carriage, as above described. The roving is wound on to the spindle in an ovoid cop, somewhat truncated at the base, and tapering at the top. When the cop has become of sufficient size, it is slid off the spindle, and is then ready to be skewered and placed in the creel of the spinning machine.

Certain manufacturers in Lancashire employ the stretching-mule with extraordinary advantage. They use for roving only the coarse bobbin-and-fly frame; after which, they subject these rovings to the stretching-mule, whereby they complete their preparation for No. 40's. With this yarn they make an excellent power-loom cloth, of an equally good appearance with that of their neighbours, though they put into the piece of 24 or 28 yards long four ounces less weight of cotton wool.

The produce of the stretching-mule or frame is a very soft roving, which must be very tenderly handled, for fear of injuring the yarn to be spun from it. By means of this frame, rovings may be equalized, and thereby certain errors of the previous machines corrected. The sets of roving turned off at regular periods by the stretcher being weighed will, in a great measure, show any variation in the grist of the cotton, and enable it to be modified by changing the pinions of the drawing-rollers. Rovings are also equalized by means of the doubling which they frequently receive at the stretching-mule; and as they are here built into a narrow conical cop, they take less room in the creel of a fine spinning mule than the bobbins of the fly-frame.

We have already stated that the rovings, whether

produced upon bobbins by the bobbin-and-fly-frame, or by Dyer's frame, or in the form of a roving-cop by the stretcher-frame, are spun into yarn on throstles or mules—two machines, which differ in the mode of winding on, exactly as the bobbin-and-fly differs from the stretching frame. The mule makes a definite length of yarn, after which it winds it up, while the operation of spinning is suspended, whereas the throstle makes the yarn and winds it up simultaneously. The mule is used generally for all numbers above 30's, throstles being now seldom used to spin so high as 40's. The quality of the yarn produced by the two machines is quite different. The throstle yarn, known under the name of water twist, from having been first produced by the machine called a *water frame*, is smooth and wiry, while the mule yarn is of a soft and downy nature. The former is usually employed for warps in heavy goods, such as fustians, cords, or for making sewing-thread, and the latter for the weft in coarse goods—as also for both warp and weft in finer fabrics. We shall first describe the throstle, which, upon the principle of Arkwright's water frame, was coincident with the use of twin rollers. The old water frame differed from the throstle, in having subdivisions in each machine, whereby one or two lengths of rollers and their corresponding spindles might be stopped or set in motion independently of the other rollers and spindles in the same machine. In the infancy of the trade, when the number of threads which broke in the process of spinning was considerable, such a convenience was desirable; but now, since practice has perfected the manufacture, it is no longer necessary, and we see throstles

with two hundred spindles and upwards, spinning for days without needing to be stopped, except for the purpose of removing the full bobbins, and putting empty ones in their places.

SECTION II.

Water-twist and Throstle-spinning.

The water-twist frame has been already described at sufficient length in the preceding volume, at page 260. It has been superseded in modern mills by the apparatus called a throstle.

The THROSTLE is a machine so simple in its construction, and seemingly so perfectly adapted to its purpose, that for many years after its introduction few persons thought of altering or improving it in any respect till about the year 1829, an invention appeared in the United States of a very singular kind. Mr. Danforth was its author, and it bears his name in the factories, though the patent was obtained in this country by John Hutchison, Esq., of Liverpool, "for certain improvements in machinery for spinning cotton, woollen, &c., as having been communicated to him by a foreigner residing abroad." The flyer, which had been hitherto deemed an essential of the water-twist system, was in Danforth's contrivance entirely laid aside. This machine, which will be afterwards described, possesses undoubtedly certain advantages over the ordinary throstle, and in particular is calculated to produce a quality of yarn less wiry than common water-twist, and well adapted, as experience has shown, for economizing cotton in the weaving of certain styles of goods. The invention has been not

more remarkable for its own success, than for the excitement it has occasioned among schemers, and the number of new throstle devices to which it has given rise. Yet no new principle of spinning has been struck out; so that the original throstle is not superseded to any considerable extent. The only advantage of the new modifications is to permit the spindles to be whirled at a greater velocity, and thereby to turn off more work from a machine of the same size; but this advantage has been in some measure counterbalanced by the increased wear of the machinery and waste of the cotton.

Before proceeding to the description of the *Throstle*, I may remind the reader, that in the preparatory machine—the bobbin-and-fly frame, the quantity of twist given to the roving should not be more than is merely sufficient to enable the rovings to unwind, without impairing their uniformity, from the bobbins upon which they were coiled; for if they be more twisted, the rovings would resist the drawing or elongating action of the fluted rollers in the subsequent processes. When eventually the substance of the roving is being extended to its utmost length, in the finishing spinning machines, it becomes necessary to increase the torsion to such a degree as to implicate the filaments so firmly together that they will resist any effort to separate them from each other. Different staples of cotton wool, and different qualities and finenesses of cotton yarn require different quantities of twist, but all well-made yarn should receive a degree of torsion sufficient to bind the fibres so intimately, that the thread will rather break across than draw out into downy ends.

In the water twist spinning-frame used by Arkwright, each head had only four or six spindles, and it could be stopped or moved by itself; but in the throstle, the drawing-rollers, instead of being mounted in fours or sixes upon independent heads, are all coupled together in one range upon each side of the frame; and the spindles of both sides are driven in common by means of bands from the long horizontal tin cylinder, which extends the whole length of the machine. The throstle consists of fewer parts, is simpler in its movements, has less friction—takes therefore, less power to drive it, and is not so costly at first as the former water-frame. It must be allowed, however, that Arkwright brought the construction and performance of his machines to a state of great practical excellence, for they turned out No. 80's, excellent yarns for warp, hosiery, and sewing-thread; and that he left little to be done in this department of spinning in comparison of what he himself accomplished. Manufacturers of cotton twist hesitated many years between the water-frame and the throstle, and though they prefer the latter in new erections, they still obtain good results from the former in well-conducted establishments like those of Cromford and Belper.

The object of the throstle is to extend the rovings into slender threads, at the same time that it twists them by the rotation of spindles or flyers, and winds upon bobbins somewhat resembling what has already been described under the bobbin-and-fly frame, but with far simpler mechanism, on account of the cohesive strength of the hard-twisted throstle thread. It consists of two roller-beams, each provided with the usual threefold set of drawing-rollers, which are

mounted upon each side of the frame. These rollers are supplied with rovings from bobbins placed upright upon skewers, fixed in shelves in the middle of the frame, which are called *creels* by the workmen. There are seldom fewer than 72 spindles in a line upon each side of the throstle, which are set from 2½ to 3 inches apart. There are, as we have already said, several modifications of the throstle, but they all consist in the form and operation of the spindle, or twisting and winding on mechanism. The oldest and most ordinary spindle is a vertical steel rod, upon whose tapering top the fly or flyer is fixed by a left-handed screw. This fly is a fork of iron or steel, having its tapering points hooked up into little eyes, to serve as guides for conducting the yarn to the bobbin revolving round the spindle-axis in the middle between them. Immediately above the top of the spindle is an eyelet of wire, which serves, like the funnel of the flyer in the fly-frame, as a guide to the thread, which is led once or twice round the arm of the fly, and then passed through one of its hooked extremities. The winding of the yarn upon the bobbin is in consequence of the friction by the bottom disc-plate of the latter upon the copping-rail, which retards its rotation, and makes it be dragged round by the yarn delivered out by the revolving fly; meanwhile the bobbins are moved slowly up and down with the regular ascent and descent of the copping-rail, whereby they receive the yarn evenly distributed along the surface of their barrels.

Fig. 66 is an end view of a common throstle of the best construction, where the manner of communicating the various movements of the mechanism is shown.

Fig. 67 is a view of a portion of the front of a throstle-frame.

Fig. 68 is a section of all the spinning parts for a single thread, drawn upon a scale double the size of the others.

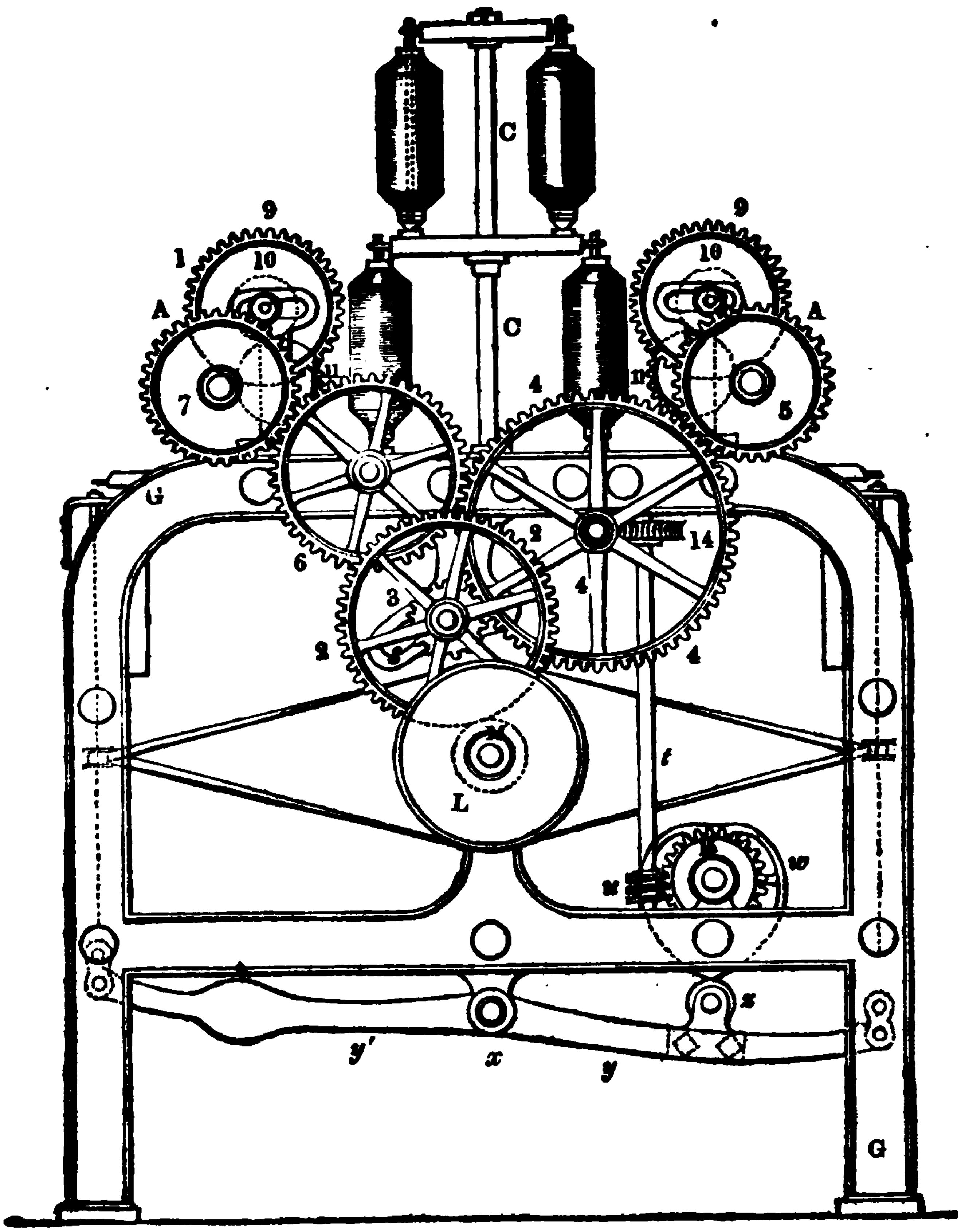


Fig.66.—End View of the Common Throstle. Scale, one inch to the foot.

A and A are the two sets of drawing rollers. These rollers rest upon upright bearings *a, a,* called heads, made fast to the roller-beam B, each head comprehending the fluted portions for six or eight several threads. The two back pairs of fluted rollers are susceptible of being shifted with their bearings *a, a* a little further from or nearer to the front pair, as already explained at sufficient length in describing the drawing-frame. This mechanism of adjustment is shown in fig. 68, which is the common one adopted in throstle-frames. Each of the top rollers, covered as usual with leather, corresponds in length to two fluted portions of the under rollers, and lies with its axis in slots of the top bearings *b;* the middle neck being covered with brasses, which sometimes carry two suspended weights, as in the drawing-frame. In the present figure, the pressure is seen to be produced upon the three corresponding top rollers by one weight C, working lever-wise round its fulcrum *d,* so as to pull down the wire *e.* This wire presses upon a *brass f,* which rests with the one of its ends upon the axis of the front roller, and with the other end upon the middle of the *brass* which covers the two axes of the two back rollers. Behind the back roller the guide bar *g* is seen sliding horizontally in slots, cast upon the heads *a,* which carry the rollers; upon this bar are wire hooks, through which the roving passes to the rollers. This bar gets a very slow traverse (or to and fro motion to the right and left alternately), by the instrumentality of a slender rod *h,* from an eccentric pin *i,* stuck in the axis of the little wheel *k,* and moved by a worm (endless screw) *l,* attached to the end of the back-roller shaft, as shown in a plan of the

end of the rollers, fig. 69. The purpose of this mechanism is to cause each thread to traverse a little way along the fluted surface, so as to change the points through which it is drawn, and thereby prevent the leather of each top roller from being channelled or

Fig. 67.—Throstle. Front View. Scale, one inch to the foot.

furrowed in one place, which it would be if the thread passed over it invariably in one direction.

C is the creel stocked with bobbins of roving set nearly upright upon skewer wires, in a double row; one for each side of the machine, and in alternate order, as shown in fig. 67.

D, D represent the spindles revolving upon their under ends in the brass steps *m, m,* made fast to the iron beam E; while the middle part revolves in the bushes *n, n,* made fast to the beam F, as clearly indicated in fig. 68. These two beams extend over the whole length of the throstle, and, as well as the roller-beam, are made fast to the strong frame-work G. In long throstle machines there are sometimes one or more transverse frames at intermediate distances to sustain these beams, and bind the whole more solidly together. *o, o* are the flys screwed upon the tops of the spindles; *p, p* are the wharves, whorls, or whirls fixed to the spindles, which serve as pulleys to turn them round by the motion of endless cords, bands, or straps proceeding from the long tin-plate drum or cylinder L, which extends through the length of the machine, and actuates the spindle movements upon both sides of the throstle, as shown in the middle of fig. 66.

q, fig. 68, is a wooden bar, to which wire hooks are fixed, to serve as guides to the threads in their way from the front pair of drawing rollers to the spindle-flys; *r* is an upright board at the back of the spindles, which screens them from dust and wind; I, I are the bobbins, consisting of a wooden tube or barrel, with two disc ends, the under end resting upon the copping-rail K. This rail has a series of holes in it for the spin-

dles to pass through. By its ascent and descent, it carries up and down the bobbins, causing them to traverse along the central spindles, and to get equably covered with yarn till they are filled.

The preceding actions and movements are produced as follows: upon the shaft of the tin-plate drum M are the usual fast and loose pulleys L (often called outriggers, from standing out from the frames or steam-pulleys, on account of their immediate connexion with the steam-driven shafts). These pulleys are moved by an endless strap from the mill shaft, *see* Chap. I., Book II., plate II. Upon M the main shaft of the throstle, fig. 67, close to L (outside of the cross end-frame), is a pinion 1 (indicated by dotted lines at M, fig. 66,) which drives the wheel 2; upon the axis of which wheel another pinion 3 is made fast to drive the wheel 4. The last wheel drives wheel 5 of the roller set A, and by means of the carrier (intermediate) wheel 6, fig. 66, the wheel 7 also upon the front roller axis of the set A′. The motion thus received is imparted by the front rollers to their respective back rollers, by means of a pinion 8, which drives a carrier wheel 9, and another carrier wheel upon the same axis drives the wheel 11 upon the back roller shaft. From the back rollers motion is given to the middle rollers upon the other end of the machine, by wheels 12 and 13, attached to their ends, and in gear with a carrier wheel, as seen in fig. 69. When it is desired to change the twist of the yarn, the carrier wheel 2, with its pinion 3, is unscrewed, and a smaller or larger pinion is put on instead of it, and adjusted in its place, so as to be in gear with wheel 4, for which purpose the slot *s* is provided in the plane of 2, which is arched

concentric with the shaft M. Thus the wheel 2 remains in gear with the pinion 1, at whatever point of the slot it may be fixed. The up and down motion of

Fig. 68.—Throstle, Section of Spinning Parts. Scale, two inches to the foot.

Fig. [illegible].—Throstle. Mechanism for traversing the Guide-bar.
Scale, two inches to the foot.

the copping-rail K is produced as follows: On the end of the axis of the wheel 4 is a worm, which drives, by the horizontal wheel 14, the upright shaft *t*, at the under end of which there is another worm *u*, driving the wheel 15, fixed upon a shaft *v*, which runs to the middle frame of the machine, where it has fixed to it a heart-wheel *w*, seen in fig. 66: *x* is a shaft running the whole length of the machine, to which are attached, at several points opposite, arms *y* and *y'*, which are connected with links *a'*, and upright rods *b'*, passing through the beams E and F, to the copping-rail K. Thus by turning the shaft *x* a little the one way or the other, one copping-rail is raised and the other is depressed. The middle arm *y* has a roller *z* attached to its top, which is alternately pressed down or suffered to rise by the revolution of the eccentric or heart wheel *w*, while the roller is kept in contact with it by the heavier arms *y'* acting as counter weights.

Upon the upper surface of the rollers (as between *b* and *f*, fig. 68,) in the line A, A, fig. 67, a travelling cone is laid in many factories for the purpose of cleaning the top rollers, or taking off from them any loose filaments of cotton. This cone is made of wood

covered with flannel, and is about one foot long, with a base four inches in diameter. It is laid loosely on the rollers, and travels by friction from one end of the roller-beam to the other, in the direction of its summit or taper end, in the course of 1,000 seconds, or about 17 minutes; if the path be 20 feet long, it will move, therefore through one foot in about 50 seconds. It is a very elegant automatic mode of wiping the top rollers, and of thus keeping the whole in good condition. The cone, after completing a journey, is removed, and a clean one substituted for it. The back top roller of the throstle-frame is of iron, large and heavy. It is called a pressing-roller, of which there are 32 in a line of 144 spindles. The cone rests against it.

In a well-mounted factory, such as Mr. Orrell's or Mr. Bailey's, there are lanes of three or four feet between the adjoining throstle-frames, so that the tenters (young women of 17 and upwards), who manage 288 spindles at least, may move about at their ease.

The quantity turned off is about 24 hanks per spindle of 30's twist in 69 hours. The bobbin of compressed roving, laid on with the spring presser already described, will last on the throstle-frame from four to five days. In some factories, with new throstle-frames, fully 30 hanks of 34's or 36's may be turned off.

In spinning 32's, the front rollers of the common throstle make 64 revolutions per minute, and the spindles 4,500. For the spinning of lower numbers, the rollers go quicker; thus, from 28's to 30's, they make from 68 to 70 revolutions. The front roller in

the tube roving-frame turns about one-tenth as fast as the spindles above mentioned. In Mr. Orrell's, for 36's, the front rollers make 72 revolutions per minute, and the spindles 4,000.

In the construction of throstle-frames, the less the distance between the front roller and the spindles, the more regularly is each portion of the yarn twisted. When the distance between *b* and *a*, fig 68, is considerable, the thinner parts of the thread become too hard twisted, and the thicker parts receive scarcely any torsion.

Throstle-yarn, for calicoes, is worth 1*s.* 4*d.* the pound, when mule-twist, spun from the same cotton-wool, sells for 1*s.* 3*d.* The greater part of the throstle-twist manufactured in this country is exported.

The common throstle spins the best yarn for the warp of velveteens; the Danforth throstle-yarn is not wiry and smooth enough on the surface for this purpose. The two do not work well together for warp in the same web, because the common throstle-yarn, being the less elastic, is apt to be snapped asunder, while the other gives way a little and remains unbroken.

Throstle spinning costs 1¼*d.* per pound in work-woman's wages.

The average price of a good throstle machine, at Manchester, is 9*s.* 6*d.* per spindle.

At Hyde, where excellent throstle-yarn is spun, 3½ hanks of 36's are the average daily quantity per spindle, or about 21 hanks in 69 hours.

I visited a great factory at Stockport, where the throstle-spindles revolved 5,000 times in the minute;

and the front rollers 90 times, in spinning 36's. These machines were constructed by Mr. Gore, of Manchester. I was informed that Mr. Axton, of Stockport, had contrived a modification of the throstle-spindle, in consequence of which he could give the front rollers a speed of 80 turns in the minute, and the spindles 7,000 turns, in spinning 24's.

The winding-on of the thread in the common throstle is effected upon the following principles: the bobbin is dragged round by the thread, and thus compelled to follow the motion of the flyer and spindle. The thread being firmly pinched by the front pair of rollers at one point, while it is rapidly whirled by the flyer at another, is exposed to continual extension, and is, at the same time, twisted. Putting the tension out of view for a moment, let us consider a certain elongation of the thread, one inch for example, by the action of the drawing-rollers. The weight of the bobbins, and their friction upon the copping-rail, which may be modified at pleasure by putting a bit of leather under their bottom discs, will, upon this supposition, be the cause of the bobbins remaining for that space behind the flyer in a state of rest, till that portion of thread, by the whirling of the flyer, has got wound up, and the former tension is once more renewed. The delivery of the thread from the drawing-roller does not take place, however, by fits, or inch by inch, but unceasingly, at a continuous rate; and hence arises a continuous retrogradation of the bobbins relatively to the spindles, which is such, that the thread given out during the revolution is in the same time wound on. This procedure in the spinning is essentially the same with what has been

fully explained in describing the operation of the bobbin-and-fly frame, but it is here simplified, as the retrogradation regulates itself according to the diameter of the bobbin, by means of the tension or drag of the thread. In the fly-frame this dragging action is impossible, on account of the loosely cohesive state of the rovings; and therefore it becomes requisite there to provide the bobbins with an independent mechanism for turning them round.

Nor is the up and down motion of the bobbins upon their central spindles, which is necessary for the equable distribution of the yarn, and which should be nearly of the same extent as the length of the bobbins, effected by the same complex mechanism as in the fly-frame. Strictly considered, this traverse motion should go more slowly in proportion as the bobbins get fuller, as is done in the bobbin-and-fly frame; but on account of the firmness of the throstle-yarn, this variation in the speed of the copping-rail, which would make the machine very complicated, may be neglected without inconvenience. The only consequence is, that the coils of the yarn become progressively more sparse upon the bobbin, as its surface is enlarged.

The chief interruption which occurs in throstle-spinning, takes place during the removal of the full bobbins, and the substitution of empty ones. This task is called *doffing*, and may be estimated to occasion a loss of about half an hour a-day with the common throstle, and three-quarters of an hour with the Danforth, but much depends upon the dexterity of the *doffer*.

The Danforth, or American Throstle.—(Hutchison's Patent.)

Fig. 70.—Lateral View of the American or Danforth Throstle.
Scale, one inch to the foot.

Fig. 71 is part of the front view.

Fig. 72 represents a cross section of one side of the machine displaying the process of spinning.

Fig. 73 is a particular modification of the spindle of this machine, as used for preparing cops for the shuttle, similar to those formed by the mule.

A is the usual fixed and loose pulley, by which the mill-power motion is given to the machine, and is abstracted at pleasure. It makes about 480 revolutions per minute. B is a pinion which drives the wheel C; and a pinion D, on the same shaft with the latter, gives motion to the wheels G, G, by means of the intermediate wheels E and F. The wheels G, G, are connected with two sets of drawing-rollers H, H, on either side of the machine. These drawing-rollers are arranged here as in the other machines for cotton spinning; the bottom ones are of iron and fluted, and the top rollers, being covered with cloth and leather, are pressed upon the former by weights K, fig. 72.

The fluted rollers are put in motion by wheels, and travel with different velocities; the front rollers making about 120 revolutions per minute, (according to the quantity of twist the yarn is to have,) the middle about 17·20, and the back rollers 12·16 revolutions, their speed being regulated by change wheels, according to the quality of the yarn. It may be easily perceived that the roving I, being introduced between those rollers, will be stretched there, and drawn to a thinner thread by the time it leaves the front rollers. This is the first operation of this spinning machine.

The next thing to be done is the twisting. *See* figs. 71, 72.

a is a spindle, fixed in the bar *m*, by a screw; *b* is a small pulley, with a tube connected to it, turning freely round the spindle *a*.

This pulley is put in motion by an endless band *c*, from the drum L, which band passes first round two spindles on one side of the machine, then round two on the other side, and, lastly, over the tightening pulley M, back to the drum. By these means four pulleys *b*, are turned, and four threads twisted by the same band. Upon the pulley *b*, and over the said

Fig. 71.—Danforth Throstle. Front View. Scale, one inch to the foot.

tube, is put the bobbin, on which the thread is to be wound after it has been twisted by the revolving pulley *b*.

To wind up the thread as it is constantly delivered from the rollers, forms the third operation. For that purpose the thread must be guided perpendicularly upon the axis of the bobbin, which is done in common throstles, as we have explained by the fly of the spindle.

In the present instance it is performed by a hollow cylinder, fixed on the immovable spindle, which causes the thread to pass round its under edge to the bobbin, which has, by the friction on the pulley *b*, a tendency constantly to revolve, and so to wind up the thread as it is delivered. This winding up would be, however, very imperfect if either the bobbin, or the guide, that is the cylinder, did not make an up and down motion in order to fill the whole bobbin uniformly with twist. It has been found the preferable way to give this traverse motion to the bobbin. The small whorls or pulleys which support the bobbins, and easily slide along the spindles, rest upon a plate *f*, which is moved up and down by the levers *o*, *o*, fig. 70. The levers get this motion by a heart-shaped plate P, fig. 70, working on a small roller, and fitted on the same shaft with the wheel R, which is driven by means of the shaft S, by a worm T, on the shaft of the wheel E, fig. 71.

The pulleys or whorls *b*, *b*, make about 6,000 revolutions per minute. To prevent the threads from running against each other at this enormous speed, in some machines the space for each bobbin is separated from the others by semi-cylindrical partitions of tinplate, made fast to a board behind them.

To be able to spin on the tube of the whorl, a cop like fig. 73, (without a bobbin,) an eccentric apparatus, must be added to the throstle, which regulates the going up and down of the pulley, according to the desired shape of the cop.

The patentee, in his specification, describes his improvements to consist "in the employment of a cir-

Figs. 72.—Cross Section of the Spinning Parts. Fig. 73. A peculiar Spindle for winding on cops. Scale, two inches to the foot.

cular rim adapted to the spindle, for the purpose of guiding the spun thread on to the taking-on bobbin, in place of the ordinary flyer. Upon the spindle a sliding roller is placed, which being connected to a movable bar, like a traversing copping-rail, ascends and descends upon the fixed spindle by the usual lever and heart movement. The whorl, whirl or pulley, turns loosely upon the spindle, its barrel bearing upon the top of the pulley, to which it is locked, when in operation, by a pin passing through the side of the bobbin, and catching against an elevated part of the whorl barrel; hence it will be perceived, that the whorl and bobbin move together: the hollow conical cap placed on the top of the spindle, where it remains stationary, is made sufficiently large to admit of the bobbin, when empty, to pass up within it.

Let it now be supposed that the end of the roving of yarn delivered from the front drawing-rollers is brought down upon the outside of the cone and attached to the lower part of the barrel of the bobbin. The pulley or whorl being then put in motion, the bobbin revolves with it, and spins the yarn as it descends into a tight thread, which flies round the cone, turning under its lower edge or rim, when, from the resistance of the atmosphere, and the light friction of the thread against that lower rim, the effect will be to twist the thread, and to cause it to wind upon the bobbin, beginning at the bottom of the barrel of the bobbin, and progressively winding up round the barrel as the bobbin descends out of the conical cap.

When the bobbin has become filled with the yarn, the conical cap must be lifted off the spindle, the full

bobbin be removed, and an empty one put in its place.

In an excellent cotton-mill at Hyde, where the common throstle-spindles turn off 3½ hanks of No. 30's warp each, int he day, the Danforth (with bobbins upon the spindles) turn off 5½. The latter yarn covers better in the web, and is therefore more economical in the manufacture of certain kinds of calico-cloth.

The Danforth frame, with small conical caps, such as are represented in fig. 73, is driven with such velocity as to yield the astonishing quantity, per spindle, of 7¼ hanks per diem of 11½ hours. There are 216 spindles in each of these machines. Such soft spongy yarns are estimated to go 40 per cent. further in the warp of a loom, than the wiry polished thread of the common throstle.

The thread in the Danforth throstle is whirled so rapidly round the conical cap, as to project in space the appearance of a continuous conical fleecy surface, intersected by four vertical lines, coincident with the centre and the two lateral edges of the cone. It is impossible for a stranger visitant to resist this visual illusion.

It is the friction of the yarn against the rims of the caps which permits the bobbins to revolve faster than the thread is delivered, and causes the winding of it on. The front rollers are usually one inch in diameter.

The operation of this productive machine is liable to certain objections. The bobbins of yarn it affords are necessarily small, softly wound, and are subject to considerable waste in the reeling upon bobbins for the warping-mill. Yet, as 40 hanks of yarn may be

spun weekly upon this throstle, while only 30 of the same number could be spun upon the common one, and as the elasticity of the former kind fits it peculiarly for weaving certain calicoes, the Danforth has many zealous partizans in Lancashire.

Gore's Patent Throstle-Spindle.

Mr. Henry Gore, the eminent machine maker of Manchester, obtained, in December 1831, a patent for a peculiar throstle-spindle, which is much esteemed by several skilful manufacturers. His improvement relates to those parts which are called the collars, for the upper bearings of spindles, retaining them in vertical positions as they revolve. For the ordinary collar, Mr. Gore substitutes a tube made fast at its lower end to the spindle-rail, in the same manner as the ordinary collar would be fixed in it; but the tube stands in a vertical position above the spindle-rail, and is interiorly larger in diameter than the spindle which passes through it, except at its upper end, which rises into the hollow within the barrel part of the wooden bobbin. The bore of the tube at that upper end is made to fit the spindle exactly, so as to form the upper bearing for the spindle, and to keep it truly vertical in its rotation.

In fig. 74, two inch spindles are represented in section. In (1) *a* is the upper end of the spindle, and *b* the lower end or toe, which revolves in the step or cup, supported by the lower spindle-rail; *c* is the wharve or whirl; *d* is the flyer screwed upon the top of the spindle; and *e*, the wooden bobbin; *f* is the tubular collar; the lower part *g* of the collar is fitted into a hole in the upper spindle-rail, and is made fast by a

nut, screwed on beneath, which draws it close down to the shoulder. The tube *f* rises and falls upon the spindle.

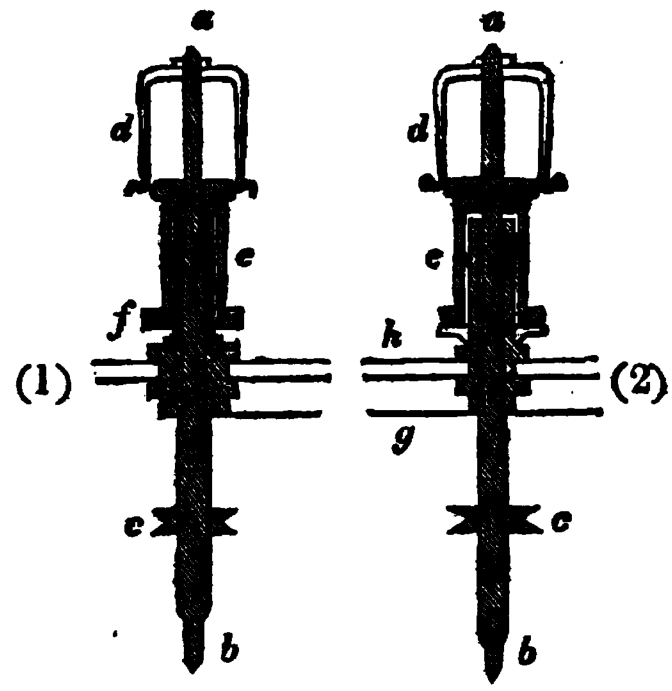


Fig. 74.—Gore's patent Throstle-Spindle.

The bore of that tube is so much larger than the spindle as to give it perfect freedom of revolution; but a brass bush is driven in tight into this wide tube near its upper end, which fits the spindle exactly, and forms its collar or upper bearing.

The upper bush of the wooden bobbin *e* is fitted upon the part of the spindle as ordinary but the lower bush is bored out larger than usual, to fit the outside of the fixed tube *f*. There is a metal washer *h*, fitted loosely upon the outside of the tube *f*, so as to slide freely up and down upon it. The flat flange of the metal washer rests upon the flat surface of the copping-rail, and the usual circular washer of woollen cloth is interposed between the base of the wood bobbin, and the top surface of the flange of the washer.

The metal washer *h* is left quite at liberty either to go round with the bobbin, or to stand still; and another cloth washer may be placed beneath it upon

the copping-rail if required. The tube *f* round which the bobbin runs being immovable, the friction which takes place between the lower bush of the wood bobbin and the outside of the tube, tends to augment the drag of the bobbin.

The upper side of the flange at the bottom of the tubular collar, is hollowed out to form a cup for the reception of oil, and every time the washer descends upon the tube, it dips into the oil, and carries up with it as much oil as will keep the outside of the tube *f* sufficiently greased for making the lower bush of the bobbin run light upon the outside of the tube.

The same tube may be fixed in the copping-rail; it will then move up and down the spindle from two to three inches, or the length of the lift, which enables the spindle to wear much longer, and makes it convenient for oiling, and when the bobbin is at the top of the spindle, the top of the tube is nearly there also, which keeps it steady.

The copping-rail must be made of a proper strength, and be fitted up in the best manner.

Fig. (2) represents a similar spindle with the addition of a thin metal tube (seen exterior to *f*,) which is fastened on the spindle just above where it comes through the top of the tubular collar by screwing as usual. This thin tube turns round with the spindle, and the lower bush of the bobbin is fitted to its outside, so as to diminish the drag of the bobbin, since the tube turns in the same direction with the bobbin.

Montgomery's Patent Spindle.

In April 1832, Mr. Robert Montgomery, of the town of Johnstone, in Scotland, obtained a patent for a modification of the throstle, as communicated to him by the American inventor. This contrivance consists in a certain addition to the flyers, which keeps them in the same position, while the spindles are caused to rise and fall, for the purpose of laying the thread regularly on the bobbins; the spindles not being permitted to turn, because they are fixed to the bottom or cross-rail. By this means he supposes the flyers and spindles will be less liable to vibrate than as they are commonly constructed.

In this machine (see *fig.* 75,) the spindle *i*, on which the bobbin is built, does not revolve, because it is made fast to the bottom or cross-rail *f*, and is moved or slidden up and down within the flyer *a, a*, so as to carry the bobbin along with it, whereby the yarn may be laid regularly upon the bobbin. This is loose, but bears upon the boss, which is fixed upon the spindle, and is allowed to run on it, in consequence of the friction or drag of the yarn, as shown at the spindle A.

The rail *h, h*, into which the spindles are secured, is made to travel up and down in the usual way, as we have already described under the common throstle.

In spinning soft yarns, they may be wound either upon the bobbin, or upon a tube or shell, as shown at the spindle B; which, when full, will be of a proper size and shape to be placed in the shuttle.

At the spindle C, the yarn is represented as laid upon the bare spindle, and in order that the friction should be as much relieved as possible, a small auxi-

liary spindle is inserted into a hollow part of the fixed spindle, as shown in section at D. The fitting of the auxiliary spindle into the other must be so easy as to allow of its moving round freely by the drag of the yarn. On the common *mule* spindle the cop is built without any auxiliary spindle.

It is to be understood that the spindles *i*, though fixed in the lower rail *f*, yet slide up and down within the flyers *a*, *a*, by the occasional elevation and depression of *k*, called the copping-rail; and that the flyers, though they revolve, are confined between the rails *b* and *k*. The flyers are turned, as usual, by bands or cords going round their wharves or whorls. The lower ends of the flyers, or forks, are connected with the

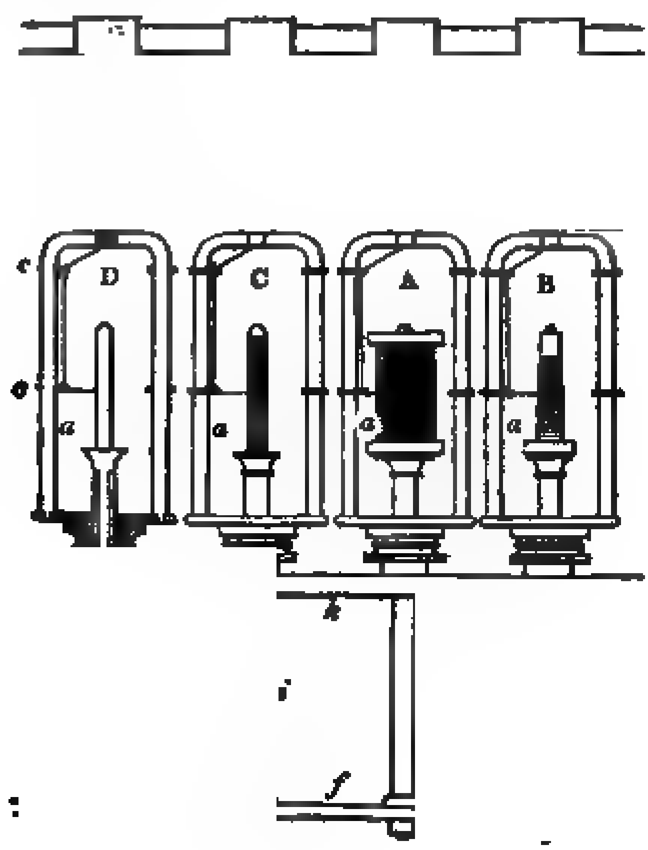


Fig. 70.—Montgomery's Throstle Spindle.

flange or rim upon the top of the wharve, "which forms the main feature of the invention, since it affords the means of building the cop upon the common mule spindle, equally with the inverted spindle, and also of building the bobbin upon the fixed spindle."

b, b, b, are the stay rails, in which the upper parts of the flyers turn; *c, c,* are the side guides for the yarn. A hole is perforated through each flyer in its centre at top, which transmits the thread from the front roller to the side guides *c, c.* The patentee claims merely the connecting the ends of the flyer with the drawing wharve or pulley, whereby he is enabled to keep the flyer in the same position, while the spindle rises and falls, and carries the bobbin or other instrument to receive the yarn up and down with the flyer, for the purpose of laying it on regularly.

Throstle-spinning costs 1¼*d.* per pound in wages; that of the self-actors costs only three farthings at most, both at No. 36's. In a certain factory five-eighths of a penny is the wages for spinning one pound of 38's. on the self-actors two-thirds of which is weft, and one-third warp or twist.

But there are remarkable differences in the productive power of different respectable factories in and about Manchester, one of them being known to turn off twenty pounds of cotton-yarn, while another turns off only eleven of the same grist, and with the same number of spindles. Of this extraordinary circumstance I was assured by an experienced spinner, who having realised a competency in the trade, had retired.

SECTION II.

The Mule, and Mule Spinning.

THE following introductory remarks, illustrative of the peculiar action of the mule, are intended to give the general reader a clear conception of the philosophical principles of cotton spinning.

Upon a minute examination of thread, it will be found that the twisting is not uniformly distributed throughout the whole of its length, but that it has taken place in different parts, inversely as the square of the diameters of these parts, or at least in nearly that ratio. Hence the thinner portions of the thread take up or appropriate a much larger proportion of the twisting power than the thicker. This peculiarity was noticed at an early period in the art of cotton spinning, though it is uncertain whether Crompton, the inventor of the mule, was acquainted with it; and it gave rise to a peculiar operation in working this machine, called the second draw. This movement is found to be indispensable in the spinning of all the higher or finer numbers, and even in making the best qualities of the middle numbers of yarn. By its means the inequalities which occur, in spite of all the precautions resorted to for equalizing the filaments in the preparation processes, are diminished, and the yarn is rendered more level, and freer from soft or weak points.

The general action of the mule may be stated as follows:—The rovings being passed forwards from their respective bobbins, set upright in the creel, through between the rollers, and their ends being attached to their respective spindles, as already ex-

plained in describing the stretching-frame, the rollers, and carriage with its spindles, are all set in motion simultaneously, the carriage being made to recede from the roller-beam at a somewhat quicker rate than the surface-speed of the front rollers, or the delivery of the soft threads, and not, as in the stretching-frame, at the same speed. This excess of velocity is called the "gain" of the carriage, and is intended to render the thread *level* upon the principle above explained, namely, that the greater quantity of twist runs into the slenderer, or weaker parts of the yarn, and obstructs their due extension; whereas, if the quantity of twist be skilfully adapted to the occasion, the thicker portions of the thread will have time to be acted upon by the gain of the carriage, till their substance is reduced somewhat nearer to the average thickness required. When the carriage has moved out about 45 or 50 inches, according to the fineness of the work, a general change takes place in the operation of the mule. The rollers suddenly stop, the spindles begin to revolve with a nearly double velocity, and the carriage slackens its pace to about one-sixth of its previous speed. This stage of the process is called the stretching, or the draw. The extension of the filaments, performed in part by the twin-roller system, is by this action carried on and completed in their softly twisted state. When the carriage, by its advance, has stretched the threads to the full extent they will bear without breaking, the second draw ceases by the stopping of the carriage, while the spindles still continue to revolve till the requisite quantity of twist is communicated, which is regulated by the twist-wheel having completed a certain number of

turns. Upon the twist-wheel shaft a finger is usually fixed, which at each revolution disengages a catch, whereby the driving-strap is allowed to pass to the loose pulley, and the whole machinery stands still. The spinner now puts down with his left hand the faller, or guide-wire, to the level requisite for guiding the threads into the proper winding-on position upon the cops of the spindles. In putting down the faller-wire, he at the same time unwinds that portion of the thread which is coiled spirally round the spindle, from its point to the nose of the cop, which he does by causing the spindles to turn the backward way, with his right hand working their main driving pulley. This operation of undoing the spiral coil is called the *backing off.*

Whenever the faller has arrived at the degree of depression suited to the winding-on of the yarn, the spinner now reverses his backward motion, and winds on the yarn by causing the spindles to turn the forward way, while, at the same time, he pushes in the carriage at a rate commensurate with the revolution of the spindles. As the carriage approaches the roller-beam, the spinner gradually raises the *faller-wire,* to allow the last portion of the threads to be coiled again in an open spiral, from the nose of the cop up to their points. One operation being thus completed, another is immediately begun.

By winding successive portions of thread upon the spindle, a conical-shaped coil of yarn is formed, which, when sufficiently large, is slid off the spindle, in which state the article is ready for the market, under the denomination of Cop Yarn. A considerable quantity of it, however,—particularly of that destined to be dyed or

shipped to foreign countries,—is unwound from the cops upon reels, and thereby made up into skeins or hanks.

The Mule, or Mule Jenny, is a machine which consists of the following four distinct members:—1. Of the drawing mechanism, or twin-roller system, which comprehends a great many fluted portions, each portion usually serving, as in the throstle-frame, to operate upon two parallel threads. 2. A movable carriage of a length equal to the roller-beam, mounted with as many spindles as there are threads to be spun. This member runs upon wheels, along three or more ground rails, horizontal, or nearly so, which allow the carriage five feet of forward and backward motion, relatively to the roller-beam. 3. The head-stock, or the machinery driving parts with the frame-work. In some mules the head-stock is placed in advance of the roller-beam towards the middle of its length, thus dividing the range of threads into two portions. The carriage here works beneath the level of the head-stock, and also divides the spindles into two corresponding portions. In many mules, however, the head-stock is put behind the roller-beam, so as to leave the whole length of the roller-beam and carriage without interruption. In the earlier and shorter mules the head-stocks were placed at one end of the roller-beam—a construction not suited to the longer mules of modern times. 4. The creel-frame, erected behind the roller-beam, for holding the bobbins filled with the rovings to be spun.

This important machine, in one of its newest and most improved forms, is represented in figures, 1, 2, and 3, plates V. and VI., being the construction preferred for the most delicate operations of fine spinning, one which combines all the varieties of mechanism in-

troduced into the mule. The frame-work is of a solidity and mobility calculated to spin 1,000 threads in one line.

Plate V., fig. 1, is a front view of the middle portion of the mule; the spindles and other apparatus being similarly extended upon both sides of the portion represented in the engraving.

Plate V., fig. 2, is a cross section of the mule, for the purpose of exhibiting the spinning parts; the carriage being shown by full lines in the position nearest to the roller-beam, and by dotted lines in its position when fully run out. Fig. 3, is a cop of yarn.

Plate VI., fig. 1, is a view of the head-stock; the carriage, front roller-beam, and creel being removed.

Plate VI., fig. 2, is a cross section of the mule, and an end view of the head-stock, to show how motion is given from the latter to the front rollers, the carriage, and spindles. Fig 3, is a plan of the spindle-drums.

Fig. 70 is a gas-light perspective view of a small apartment fitted up with mules, upon the older construction of head-stock apparatus, for spinning low numbers of yarn. Here the overlooker, spinner, piecer, and scavenger, are shown in their respective positions.

When the spinning operations begin, the rollers deliver the equably attenuated rovings, as the carriage comes out, moving at first with a speed somewhat greater than the surface-motion of the front rollers. The spindles meanwhile revolve with moderate velocity, in order to communicate but a moderate degree of twist. When the carriage has advanced through about five-sixths of its path, the rollers cease to turn or to deliver thread. The carriage thenceforth moves

at a very slow pace, while the speed of the spindles is increased to a certain pitch, at which it continues till the carriage arrives at the end of its course. The spindles go on revolving till they give such an additional twist to the threads as may be desired, the degree of it being greater for warp than for weft, and for bobbinet and book-muslin yarns than for the yarns of softer fabrics. The spindles then stop, and the whole machine becomes, for the moment, insulated from the driving shaft of the factory. Now the delicate task of the spinner begins. First of all, he causes the spindles to make a few revolutions backwards, by turning a winch-handle that acts on a pulley which moves all the spindle-drums at once. In this way he takes off the slant coils from the upper ends of the spindles, to prepare for distributing the 54 or 56 inches length of yarn just spun properly upon their middle part. This retrogradation of the spindles is the process already described under the name of backing off.

The spinner having seized the faller-rod with his left hand, gives the faller-wire such a depression as to bear down all the threads before it to a level with the bottom of the cop, or conical coil, of yarn formed, or to be formed, round the spindles. While his left hand is thus nicely applied, under the control of an experienced eye, his right hand slowly turns the handle of the pulley in communication with the spindles, so as to give them a forwards rotation, and his knee pushes the carriage before it at the precise rate requisite to supply yarn as the spindles wind it on. Three simultaneous movements must be here very delicately and dexterously performed by the mule-

spinner; first, the regulation of the faller, or guide-wire, continually varying in obliquity; secondly, the rotation of the spindles, perhaps 1,000 in number, at a measured speed; and thirdly, the pushing in of the carriage at such a rate precisely as to supply yarn no faster than the spindles take it up. In fine spinning upon a mule, like the one represented in the engraving, where nearly 1,000 threads were spun at once of almost invisible tenuity; the skill and tact required in the operator deserve no little admiration, and are well entitled to a most liberal recompense. In the process of winding-on, so as not to break the threads, and in coiling them into the shapely conoid, called a cop, the talents of the spinner are peculiarly displayed. As the carriage approaches to its primary position, near to the roller-beam, he allows the faller-wire to rise slowly to its natural elevation, whereby the threads once more coil slantingly up to the tip of the spindle, and are thus ready to co-operate in the twisting and extension of another stretch of the mule. Having pushed the carriage home, the spinner immediately sets the mule again in geer with the driving-shaft, by transferring the strap from the loose to the fast steam-pulley, and thus commences the same beautiful train of operations. It is during the few instants after the carriage starts that the lively little piecers are seen skipping from point to point to mend the broken threads. Whenever it has receded a foot or two from the delivering rollers, the possibility of piecing the yarn being at an end, the children have an interval for repose or recreation, which, in fine spinning at least, is three times longer than the period of employment. The spinner likewise has nothing to do till after the

completion of the fresh range of threads, when he once more *backs off* the slanting coil, and winds on the "stretch."

A, A, plate V. figs. 1, 2, is the triple pair of drawing rollers working in heads fixed upon the roller-beam, B.

C is the *creel*, or rails, in which the roving bobbins are arranged in three, or sometimes in four rows, one over and behind another, according to their size and the smallness of the cop upon the spindles. The creel and roller-beam are both supported by frame-pieces of strong cast-iron, such as D.

E, E, is the carriage to which are attached three or four horizontal bars, F, which rest upon the axes of the wheels, G, G. The wheels run upon the rail-way, H. The carriage is constructed of two long planks, *a* and *b*, extending through its whole length, and bound with cross pieces of wood or iron made fast by screws. There are likewise diagonal braces to prevent any tendency to warping or vibration. Moreover, two, or sometimes four iron rods are attached diagonally along the bottom of the carriage from end to end, or from the middle to the end, and secured at their extremities with screw bolts and nuts, for the purpose of drawing it into a straight or square form, in case it should become uneven, or, as workmen say, untrue, in the slightest degree. Upon the carriage planks, or beams, a frame-work, *c*, *d*, is built, in the forepart of which the top-bushes and bottom steps of the spindles, I, are fixed. The spindles themselves are set in an inclined position, sloping towards the roller-beam, so that in their usual revolution they may twist the threads round their points without tending to wind them upon their surfaces, during the coming out of the carriage. *e*, *e*, are

little pulleys called wharves, fixed upon the under part of the spindles, each at a different height, throughout a range of eight or sixteen adjoining spindles. By this means the echellon arrangement, seen in fig. 1, plate V., is produced.

K is a series of drum cylinders made usually of tin-plate, each being furnished with two grooves round their upper end, for receiving their driving bands. Their smooth sides receive and work the moving bands or cords of two ranges, containing from sixteen to thirty-two spindles. The uppermost cord impels the first spindles of the adjoining two rows; the second cord moves the second spindles of the same ranges, and thus in succession. *f* is a long, slender iron shaft, lying in the bearings *g*, over the carriage from end to end, and provided with small arms *h*, *h*, called the *fallers*. These bear the faller-wire *i* (pl. V., fig. 1), which serves to depress all the threads from the points of the spindles (see dotted lines under *i* in fig. 2), and to bring them upon a level with the bottom of the cop in the act of winding-on already explained. The gradual rise of this wire allows the thread to be duly distributed upon the cop. Since the most expert spinner can hardly be expected to apply the faller with geometrical precision, so as always to coil on the yarn proportionally to the rotation of the spindles and to the advance of the carriage before his knee, there is another regulating wire called the counterfaller. This consists of lever arms *l*, fig. 2, having a fulcrum attached to the frame-work of the carriage. These arms bear at their points *m*, a wire which extends horizontally like the faller, from end to end, but beneath the surface level of the threads. On the other ends of these levers

are weights *n*, which cause the wire *m* to rise so as to balance the threads nicely after their depression by the faller-wire *i*, and to straighten them when loose. Should the tension be too great, the counterfaller lever itself must be depressed. It is obvious that the weights, *n*, should be directly proportional to the number of the spindles, and inversely to the fineness of the yarn.

L, L, pl. VI. figs. 1 and 2, show the containing frames of the head-stock, which serve partly to support the roller-beam, B. Two mules are generally fitted up together, back to back, so that the frame of the head-stock of each mule sustains partly its own roller-beam, and partly that of the next mule, as may be understood from inspecting the broken-off arm, *o*, pl. VI. fig. 2. By this arrangement, two neighbouring mules stand always with their faces fronting each other, and are worked together by one spinner, who conducts the winding-on of the yarns, and the *putting up* of the carriage of the one mule, while the mill-shaft power is driving the other mule in the process of drawing, twisting, and stretching. *See* fig. 76.

The motions are communicated as follows :—

M, M′, M″, are three horizontal driving or steam-pulleys, plate VI., figs. 1 and 2, set upon an upright shaft *p*. They are driven by a band from a broad pulley upon an upright mill-shaft, see plates I. and II., which impels the two mules which stand back to back. M, the lowest, is usually the loose pulley, to the surface of which the strap is shifted when the machine throws itself out of geer after finishing a stretch. The pulley M′, is fixed along with the toothed wheel 1, upon a boss (or thick part of the shaft), which turns loose upon the shaft, *p, p*. The pulley M″, is *fixed*

upon the shaft p, along with the toothed wheel, 2. These wheels, 1 and 2, are constantly in geer with the wheels 3 and 4, fixed upon the upright shaft, q, from which the twisting motion is conveyed to the spindles by the twist-pulley, N. This pulley is provided with six grooves of progressively increasing diameters, calculated to vary the velocity of the spindles.

Upon the shaft, p, is a bevel-wheel, 5, which moves the bevel-wheel, 6, turning upon a horizontal shaft, r. From this shaft motion is given to the drawing-rollers in the following way. The bevel-wheel, 7, upon the shaft, r, drives the wheel, 8, upon the shaft, s; whence the motion is communicated by two bevel-wheels, 9 and 10, to the shaft, t, which connects the front rollers of each side of the machine. The motion of the rollers is stopped by pushing aside the wheel, 8, out of geer with 7, by means of the lever, u; for this reason, the shaft, s, has been called the tumbling shaft.

From the shaft, r, two motions with different velocities are produced in succession to take out the carriage of the mule. The first and quicker motion is given by wheel 11, to the large horizontal bevel-wheel, 12, called the mendoza, upon the upright shaft v; the lower end of which bears a rope pulley O. Upon this upright shaft, v, is another horizontal bevel-wheel, 13, of the same size as 12; which wheel is thereafter put in motion by the small bevel wheel, 14, fixed upon the axis of the large wheel, 15. This is driven by the pinion 16, and therefore gets a slower motion than the wheel, 14. The bevel-pinion, 11, is put in geer with its bevel-wheel, 12, in consequence of the shaft v being lifted up by the rising of the bearing step x, under the action of the lever, y. (Pl. VI., fig. 1, and 2, at bottom.) By the

subsequent depression of the lever, the shaft *v* falls, and brings the wheel, 13, in geer with its driving-pinion, 14. After the carriage has run out to the end of its course, these bevel-wheels, 13 and 14, are also thrown out of geer by the depression of the wheel, 15, and its attached bevel-pinion, 14; which are thus disconnected with their respective wheels, 16 and 13. How these various motions are given will be presently explained.

We shall now describe how the carriage is taken out by the rope pulley O. In the front of the mule, at the spot to which the carriage comes on completing its stretch, is a horizontal rope pulley, P (plate V.) turning freely upon an upright stud or bolt, fixed to the floor, and is, with the shaft of the pulley O, in a line parallel to the course of the carriage. Round these two pulleys an endless rope, *z*, passes; with one looped branch of this rope, a bolt, *a'*, is connected, which is attached to the carriage E. Hence, by turning the shaft, *v*, with the pulley O, first quicker and then slower, a correspondent rate of motion will be communicated to the carriage; and when the shaft stops, the carriage will be fully run out.

We shall next explain how the spindles receive their whirling motion all the time they go out and in with the carriage. *See* plate V.

From the twist-pulley, N, in the head-stock at the back of the mule, an endless band proceeds, one branch of which goes round the grooved horizontal pulley, *b*, beneath the carriage, and then turns over the guide-pulley, *c'*, (pl. V. fig. 1), for the purpose of driving all the drums, K, situated on the right-hand side of the carriage, by passing round their topmost grooves, and

returning round their second grooves in order to get at the left-hand side of the carriage. After driving all the drums there, it then proceeds to the middle of the machine, passes over the guide-pulleys, *d′* and *e′*, in the carriage (as shown by dotted lines in fig. 43), to a horizontal pulley, Q, which revolves freely upon the same upright stud or bolt, with the rope-pulley, P, and joins thereafter with the end of the band at the twist-pulley, N; from which the line of its course began. Thus it appears that the drums, K, are turned by the twist-pulley N, quite independent of any motion or position of the carriage, as the endless band is kept of uniform length in consequence of the end pulley Q, and the guide-pulleys *b′ c′ d′ i′* of the carriage, revolving within the coils of the endless band.

A general idea of the working of these band-coils round the twist-pulley, N, the end pulley, Q, and the carriage drums, K, may be formed by inspecting plate VI., fig. 3, in which the carriage, represented by the line, E, E, is seen to be movable backwards and forwards between the fixed centres of the pulleys, N and Q; while the coils of the band continue to move round the drums. In fig. 3 the revolving parts are shown in one plane; whereas in the mule itself they lie in different planes, as may be seen in plates V. and VI., and are conducted through their changes of plane by the several guide-pulleys.

Upon end of the shaft, pl. VI. *r*, there is a worm which drives the wheel, *f′*, attached to an oblique shaft, *g′*, on the under end of which are two little arms, *h′* and *i′*, by which the strap is made to shift upon one or other of the pulleys, M, M′, and M″, by the guide-fork, *k′*. In beginning to stretch, the spinner moves this fork

opposite to the top pulley, M″, by means of the handle, at top *l′*, which draws up the rod, *m′*. To this rod a small shoulder, *n′*, is fixed, which moves in a slot of the bracket, *o′*, and rests at the beginning of the stretch on the top notch of the serrated crank lever, *p′*, which is pressed against it by a weighted end. The slant shaft, *g′*, in its revolution, at a certain period of the stretch, strikes with one of its arms, *h′*, against the top of the lever, *p′*, and thus permits the rod, *m′*, to fall into its second notch, by which the fork, *k′*, shifts the strap to the pulley, M′, under the first one. In the former motion, the wheel 2, was driving the twist-pulley shaft 4; in the latter, the wheel 1 is driving the wheel 3; and in consequence of the different ratios of their diameters, the twist-pulley is driven with increased speed, which takes place, as before said, when the stretching is completed. After the stretch is finished, the shaft, *g′*, strikes with its second arm, *i′*, against the lever, *p′*, and thus lets the fork, *k′*, fall upon the undermost pulley, M, which being a loose one, brings the machine to repose. Below is a little arm, *q′*, upon the lever, *p′*, which is connected by a bell-crank and a wire lying upon the floor, which may be drawn if any accident should occur during the stretching, in order to stop it, by letting the rod, *m′*, fall down out of the notches, and thereby shifting the strap to the loose pulley, M.

At the same time that the twist-pulley gets its quick motion, by shifting the strap from the pulley M″ to the pulley M′, the drawing rollers are disconnected from the machinery, and brought to rest by moving the wheel 8 out of geer with 7, by the lever, *u*. The shaft, *v*, is also depressed, so as to throw the wheel 12 out of geer with 11, and to place wheel 13 in geer with wheel 14, by which change, the rope-pulley, *o*, upon the mendoza

shaft, v, moves the carriage during the rest of the course at a slow speed, to give the finishing stretch to the length of yarn already given out by the rollers, while it continues to receive twist.

R, plate VI., fig. 2, is a balance lever, turning on a fulcrum, r', furnished at the one end with two hooks, s' and t', and at the other end with two catches, which act upon two different pins, u' and v', on the ends of the upright levers, S and T, (seen in plate VI., fig. 2, and partially in fig. 1.) These upright levers swing with two fulcrum shafts, x' and y', in bearings fixed to the frame of the head-stock. To the shaft, x', are fixed two curved arms, a'' and b'', fig. 1. The first, a'', working in a slot of the curved lever, u, and the second, b'', connected by a rod, c'', with the lever, y, in which is fixed the bearing, x, of the mendoza shaft, v. When the carriage, in its recession, makes the handpiece, w', press on the hook, s', of the balance-lever, the catch, u, at the other end of the lever, is raised a very little, so as to disengage the pin of the upright-lever, S, whilst the longer catch of v' retains its hold of the other upright lever, T. The bottom of the lever, S, swings back, and is caught against the pin, d'', on the balance lever, R, while, by its upper arm, a'', it moves the curved lever, u, and throws the wheel, 8, out of geer with 7,—thus setting the rollers at rest. The other arm, b'', attached o the lever shaft, x', by letting down the step, x, of the mendoza shaft, v, brings the wheel 13 into geer with 14. These two motions take place at the commencement of the quick twisting; and as this point varies for different numbers and qualities of yarn (as warp and weft), the hook, s', may be shifted on the balance-lever, R, to its proper place of adjustment, according to the judgment of the spinner. After the carriage has

reached to nearly the end of its course, the hand-piece, w', strikes upon the second hook, t', depresses the end of the balance-lever still further, by which the catch, v', is lifted from the pin at the lower end of the lever, T. By this means, the lever is allowed to swing with its axis, y', and to depress with the curved arm, e'', of the shaft the wheel 15, and of course the bevel-pinion 14, which revolves on a stud fixed to the end of that arm; by which process the mendoza shaft is now disconnected with every motion, and causes the carriage to stop, while the additional twist proceeds till the strap is shifted upon the loose steam-pulley, as above described. *See* fig. 2, plate VI.

Now the spinner's task begins: he lays hold of the handle, U, and pulls its shaft, f'', along with the bevel-wheel, 15, into geer with the bevel-wheel, 16, fixed on the upright shaft, c', which carries at its lower end the band-pulley, b', already described. The shaft, f'', is sustained in its present place by the pressure of the end of the bar, g'', against *its* end. The bar, g'', slides up and down in a staple guide, i'', by the action of a weight on a lever attached, with one end to the bar, and its fulcrum on the carriage, (as shown at k'', k'', pl. V. fig. 1,) and thereby presses with its end the step-bearing, h'', of the shaft, f'', which bearing swings round about the fulcrum, l''. The handle, U, of the box-organ being connected by the wheels, 15 and 16, with the pulleys, b' and c', and the drums, K, which drive the spindles, the spinner now turns the handle slowly, causing the spindle to revolve backwards through a few turns, by which means he backs off the oblique coil of yarn last spun; whilst, with his left hand, he depresses the faller to begin the winding-on from that part of the cop which has already acquired

the proper diameter which the middle cylindrical parts of the cop is to have. At the same time he begins to push in the carriage, and to turn the handle in an opposite direction, so as to wind on the yarn at the same rate as he approaches to the roller-beam, gradually lifting up the faller so as to form a conical surface above. On his coming near the rollers, a piece of iron projecting from the plank, *a*, of the carriage, strikes against the lever, S, and replaces it in its catch, *u'*, of the balance-lever, R; while the fork, *w''*, attached to the lever, S, guides and pushes the other upright lever, T, into its catch, *v'*. The mule being thus made ready to begin a new stretch, the spinner lays hold of the lever-handle, *l'*, and thereby slides up the rod, *m'*, and brings the strap upon the uppermost steam-pulley M''. With the rod, *m'*, is connected an S arm, *n''*, (plate VI., fig. 2,) which goes underneath the weighted end of the lever, *k''*, (seen in dotted lines, plate V., fig. 1,) and lifting it up presses down the bar, *g''*, which kept the bevel-wheels, 15 and 16, in geer, whereby the shaft, *f''*, with the wheel, 15, is allowed to fall down by its weight out of the teeth of the wheel, 16. Thus the handle, U, remains out of geer while the carriage is in the act of stretching.

The spinner requires much skill and dexterity: first, to back off; secondly, to wind on the yarn without breaking; and thirdly, to give the cop such a shape as may facilitate the winding off, either in the shuttle, or upon the reel. Much time is often lost by the spinner at the beginning of the winding-on, in the formation of the double cone, or foundation of the cop, as represented in plate V., fig. 3, which shows the double cone, *a*, *d*, *b*, *c*, first formed, on the upper part of which the cone is built upwards, so as to form a

cylindrical middle part, *a, b, e, f.* Such a cop as contains most yarn in the least dimensions, is the best for unwinding, but it is very seldom formed with due accuracy by hand.

From the front roller, motion is transmitted to the back roller of each side of the mule by the usual carrier-wheels, as in other spinning-machines, (see plate VI., fig. 2;) and from the back roller to the middle roller, by wheels on the right-hand end and left-hand end of the roller-beam.

In the mules, generally, and sometimes in the throstles, instead of covering the top rollers with flat boards faced with flannel, a series of loose friction rollers, covered with flannel, are laid in the hollow between the front and middle top rollers, which, revolving with different velocities, give an intermediate velocity to the loose one, which thus wipes or rubs off any adhering fibres of cotton.

The proprietor of one of the best fine-spinning mills in Manchester informed me that in good mule-spinning there should be no more stretching than is indispensable to make the yarn level. The second stretch, in fine spinning, amounted formerly to 12 inches, now it never exceeds 6.

The creel-steps, in which the lower ends of the bobbin-skewers stand, both in mule and throstle-frames, are minute conical cups made of glazed pottery, which cost two-pence halfpenny per gross.

The time taken to make a stretch and wind it on, increases with the fineness of the yarn, and differs considerably for the same numbers in different mills, according to the quality of the yarn, the goodness of the machinery, and the dexterity of the spinner.

In one very large factory at Manchester, in a mule

containing 512 spindles, which was spinning No. 30's. weft, three stretchers of 56 inches each were made in 68 seconds, being a stretch in rather less than 23 seconds. Another mule in the same factory, which contained 340 spindles, and was spinning 40's for warp, took 74 seconds for three complete stretches, being a stretch in rather less than 25 seconds.

The *stretcher* mule of a fine-spinning mill makes four stretches in 65 minutes, being one stretch in about 16 minutes.

In the lower counts of 34's and 36's, 25 hanks weekly per spindle may be considered a fair average of mules in well-going mills.

One experienced cotton spinner informed me that warp is twisted to the left hand, and weft to the right.

In one factory a fine-spinning mule made a stretch of yarn, No. 170's, excellent quality, in one minute. In another, I found that a minute and a half was consumed in making similar yarn. When the number exceeds 220's, nearly two minutes are taken to a stretch in some factories. The number of breakages of threads is also an important object of comparison. In one fine-spinning mill at Manchester I have observed the number of threads which require piecing at every stretch to be three times as great as those in another mill spinning like numbers. The quality of the yarn is tried by several tests. The weight which is just requisite to break it determines its strength; and if this weight be uniform over successive lengths, the yarn is of uniform strength. Its levelness is tried by drawing it in a wet state between the fore-finger and thumb, a test in delicate hands susceptible of great precision. The uniformity and sufficiency of the twist, as well as the softness, smoothness, and firmness of the texture,

must all be taken into account, and are readily ascertained by the experienced *taker in of work* in a cotton-mill.

The second stretch, to draw down and equalize the yarn, is seldom used in spinning the low numbers, by which much time is saved.

About 14 years ago, 13 per cent. of the threads used to break at every stretch; 3 or 4 per cent. are reckoned a large proportion now. In fact, the best spinning mules that I have observed, both in this country and in Alsace, seldom break more than 1 per cent. of the threads in each stretch—a circumstance indicating surprising perfection in the manufactures, if we consider the feeble cohesion of the finer yarns.

The degree of twist communicated to a given length of yarn may be readily found in the throstle by comparing the surface motion of the delivering rollers with the rotatory speed of the spindles: thus when the front rollers, one inch in diameter, turn 90 times per minute, they give out 282¾ in that time, while the spindles make 5,000 revolutions; the twist communicated is therefore 17 7-10th turns in every inch; but in the mule the relative velocities of the front rollers and the spindles are not so directly observable.

In the mule the speed of the spindles should never exceed 4,500 turns in the minute, lest their upper part may be made to oscillate and damage the yarn. Mr. Montgomery has given the following Table of Draughts, calculated for a crown wheel of 72 teeth, a back roller wheel of 56 teeth, and a front roller pinion of 18 teeth, the diameter of the front roller being one inch, and of the back roller 7-8ths; showing the draughts produced by any grist-pinion containing from 20 to 35 teeth.

Grist Pinions.	Draughts.	Grist Pinions.	Draughts.
20	12·8	28	9·14
21	12·18	29	8·82
22	11·63	30	8·53
23	11·12	31	8·25
24	10·66	32	8·00
25	10 24	33	7·75
26	9·84	34	7·52
27	9·48	35	7·31*

In the Scotch cotton-mills, 25 twists are allowed to the inch for warps of No. 50, and wefts of No. 60; from which, if a standard be taken, we may calculate approximately the proportional number of twists to be given to another number of yarn,—say 70, by the following rule:—

$$\text{As } 50 : 25^2 : : 70 : x^2$$

$x^2 = \dfrac{625 \times 70}{50} = 875$; of which the square root is 29·6, showing on this principle that warp-yarn, No. 70, should have 29·6 twists per inch. This rule requires, however, to be modified in its application to fine numbers. The following empirical rule has also been offered as affording a ready approximation. Multiply the square root of the intended number of hanks per pound by $3\frac{3}{4}$, if for warp-yarn, and by $3\frac{1}{4}$, if for weft-yarn; the products will be the respective twists per inch. Thus in the above example; the square root of 70 is 8·366, which multiplied by $3\frac{3}{4}$ is

* Theory and Practice of Cotton-spinning, p. 176.

31·372, being nearly two twists above the quantity given by the former rule. Were the square root multiplied by $3\frac{1}{2}$, the product would give a better accordance. The former rule may, therefore, be considered as the more correct of the two.

But the exact calculation for mule spinning, or the elongation of a given number of roving in passing through the drawing-rollers, and degree of twist which the thread receives from the spindles, may be readily made on the following principles. Suppose the central wheel on the rim to have . . . 48 teeth

The second conical wheel fixed on the upper end of the bevel or tumbling shaft	54
The third bevel-wheel, on the lower end of this shaft	35
The fourth bevel-wheel, on the shaft joining the back rollers . . .	52
The pinion on the same shaft . .	24
The spur-wheel on the adjoining parallel shaft driven by that pinion . .	90
The change pinion	21
The wheel on the end of the back rollers, driven by the pinion . . .	42
The wheel on the outer end of the back rollers	25
The pinion on the outer end of the middle rollers	22
The diameter of the back and of the second rollers	$\frac{3}{4}$ inch
The diameter of the front rollers . .	1

After a complete revolution of the rim, or great fly-wheel of the mule, we shall have the following

changes of position according to the common calculations of toothed-wheel work:—$\frac{48}{54} \times \frac{35}{52} = \frac{6}{10}$ or 0·60; whence 1 : 0·60 denotes the relative velocity or movement of the rim-wheel to the front roller; that is to say, when the rim-wheel has made one complete turn, the front roller has made only six-tenths of a revolution.

$\frac{24}{90} \times \frac{21}{42} = \frac{13}{100}$ or 0·13; whence we have the relative velocities of the rim-wheel, the front roller, and the back roller as the three numbers :—1; 0·60; 0·13, or 100; 60; 13.

As the diameter of the front roller is one inch, its circumference is about $3\frac{1}{6}$, or 38 twelfths; but as it makes only $\frac{6}{10}$ of a turn, the movement of its circumference will be $0·6 \times \frac{38}{12} = \frac{228}{120}$ or 22 twelfths and $\frac{4}{5}$, whilst the rim makes one revolution.

The back roller being $\frac{3}{4}$ or $\frac{9}{12}$ of an inch in diameter, has a circumference of about 28 twelfths; but as it makes only $\frac{13}{100}$ of a revolution, its surface movement by one turn of the rim will be $\frac{9}{12} \times \frac{13}{100} = 3·64$ twelfths of an inch only. Hence the 3·64 twelfths of roving taken in by the back roller, furnish 22 twelfths and $\frac{4}{5}$ of elongated thread; showing the draught to be $\frac{2280}{364} = 6·26$ times. Hence, if the roving in the creel furnished by the fine bobbin-and-fly-frame was of No. 8, the resulting yarn upon the mule, without any stretching by the gain of the carriage, would be No. 50; that is the number 8 multiplied by 6·26.

The slight draught which takes place between the back and middle rollers, in consequence of the difference in the number of teeth in their respective wheels, can introduce no change in the total elongation now

stated; this being made merely at two steps, the first and smaller portion between the back and middle rollers, the second and greater between the middle and front rollers.

The relative speed of the back and front rollers may be changed by substituting greater or smaller pinions, for the existing change pinion previously described.

As to the twist of the thread, it may be calculated still more readily from the following data:—the diameters of the groove in the rim or fly-band groove, that of the twist-pulley groove, the drum-band grooves, and the wharves on the pulleys. The guide-pulleys merely change the direction of the motion, without affecting its degree. We shall, therefore, find that for each turn of the fly, which causes 22 twelfths and $\frac{8}{10}$ of an inch of thread to be delivered, the spindles will make with the above dimensions 68 revolutions and $\frac{4}{10}$, or 36 turns for every inch of yarn given out; but this twist is only about two-thirds of what ought to be given, the remainder being communicated after the stretch is finished, as already described.

The pinion on the shaft which joins together the front fluted rollers has 16 teeth, and drives the Mendoza wheel of 90 teeth; their relative motion is denoted by $\frac{16}{90} = 0 \cdot 18$ nearly, for each turn of the pinion shaft; but as with the front rollers it makes only $0 \cdot 6$ of a turn, the Mendoza wheel will consequently make only $0 \cdot 11$ of a turn $= 0 \cdot 60 \times 0 \cdot 18$, in the same time that the rim-wheel makes one complete revolution. If the diameter of the Mendoza pulley which takes out the carriage be 68 twelfths of an inch, its circumference will be 213 twelfths; but as it makes only $\frac{11}{100}$ of a turn,

its surface motion will be only 23 twelfths and $\frac{43}{10}$ of an inch, exceeding by $\frac{63}{100}$ of a twelfth the length of thread delivered by the front rollers. This quantity, equal to about $\frac{1}{19}$ of an inch, is the elongation which the yarn receives from the motion of the carriage, or the gain upon the stretch for every revolution of the rim. If the stretch be 56 inches = 672 twelfths of an inch, the carriage will come out in about $28\frac{2}{3}$ revolutions of the rim $= \frac{672}{23 \cdot 43}$, and the twist will be completed by $14\frac{1}{3}$ turns, constituting in all $50\frac{1}{3}$ turns of twist for No. 50, at the rate of one twist per inch for each number. The wheel which works in the worm cut in the boss on the end of the rim-shaft, should have therefore 50 teeth in this construction. The gain of the stretch, produced by the excess in the motion of the carriage above the surface motion of the front rollers upon each series of threads, will be equal to $50\frac{1}{3} \times 0 \cdot 63 = 31\frac{1}{2}$ twelfths of an inch, or 2 inches $7\frac{1}{2}$ twelfths in a mile, where no second stretch is employed.

If two and a half stretches = 140 inches of yarn, or 11 feet and 8 inches, be formed per minute upon each spindle, 700 feet will be made each hour, and 8,050 feet in $11\frac{1}{2}$ hours = $2{,}683\frac{1}{3}$ yards $= 3\frac{1}{5}$ hanks nearly of 840 yards each; and if each mule contains 360 spindles, of which a spinner works a pair, he will turn off $3\frac{1}{5}$ hanks $\times$ 720 = 2,204 hanks of 50's, = 40 lbs. of yarn in the day's work.

As the spinner works a pair of mules at a time, were the headstocks placed in the middle of the roller-beam of each mule, they would interfere with each other, for which reason they are placed each a little to the right of the centre, leaving the larger space to the

left where the spinner stands. This inequality varies, but is frequently in the proportion of two to three, so that in a mule of 360 spindles, 144 are on the left side of the head-stock, and 216 on the right.

The following method of computing the draught and twist in the mule is somewhat simpler than the preceding. As the wheel on the rim-shaft has in many mules the same number of teeth, namely 50, with that on the front roller, both may be left out of view. Multiply the number of teeth in the driving-wheels for one product, and the number of teeth in the driven wheels for another. Divide the former number by the latter, and the quotient will be the relative revolutions of the front roller, which, multiplied by the revolutions of the rim per minute, will give the speed of the front rollers in that time. Let there be 35 teeth in the wheel upon the lower end of the bevel-shaft, and 54 in that upon its upper end $\frac{35}{54} = 0 \cdot 648$; and if the rim make 90 revolutions per minute, then $90 \times 0 \cdot 648 = 58 \cdot 82 =$ the number of revolutions of the front roller per minute.

The rotation of the spindle, compared with the speed of the rim-band, may be thus computed. If the diameter of the rim be 36 inches, the groove for the band in the twist-pulley be 14 inches, and that of the drum band be 15, the whorls or wharves being one inch in diameter; multiply the diameter of the rim by that of the drum groove, and divide the product by the diameter of the twist-pulley groove; thus, in the above case, $\frac{36 \times 15}{14} = 38\frac{4}{7} =$ revolutions of the spindle for one of the rim. If this number be multiplied by $90 =$ the rotations of the rim per minute, the product $3{,}471\frac{3}{7}$ is the revolution of the spindle per minute.

In the second speed of the rim, its revolutions may be 115 per minute, whence 115 $\times$ $38\frac{4}{7}$ =4,553 turns of spindle per minute in second speed.

General Explanation of the Self-actor Mule.

The rollers deliver the yarn, the carriage is taken out, and the spindles are turned by bands from tin drums to which motion is given by the twist-pulley, M, as in a hand-mule.—*See* fig. 77 and 79.

The next motion is backing-off the spindles to uncoil a sufficient quantity of yarn to allow the faller to descend, and carry with it the yarn to the point where it is to begin to be wound on the spindles. The carriage is then drawn in, and the spindles receive the yarn so distributed as to form a cop. These operations are regulated by machinery, instead of by hand, as in a common mule.

On the rim-shaft, *a*, are three pulleys of equal diameter, of which one, C″, runs loose on the shaft to receive the strap, D, when out of action. C′ is always revolving, and works a leather friction-pulley to turn the cam shaft, *b*, one quarter round to perform a change at four different times during one complete motion of the mule; these four changes are,—1st, to put the front rollers in motion to draw out the carriage, to turn the spindles to give twist to the yarn; 2d, to stop the rollers and carriage, and give an extra quantity of twist to the yarn if required; 3d, to back off the spindles, and lower the faller to the point where the yarn should begin to be wound on; 4th, to draw in the carriage by means of a band working on a scroll, F, and to turn the spindles at the required speed to receive the yarn distributed so as to form a cop. C is

turned by the strap, D, to take out the carriage, and give twist to the yarn, while the carriage is going out, and after it is stopped.

C is then released from the strap, D, and a crossed strap, D′, slides from the loose pulley, C″, to C′, to back off the spindles and lower the faller. To draw in the carriage and wind on the yarn, strap D slides again on to C′, and thereby gives motion to the scroll F, to the quadrant, P, which regulates the winding-on of the yarn, and to the faller which gradually rises and guides the yarn to be wound on the spindles. The winding-on of the yarn is performed thus:—there is a drum, or barrel, G, connected by wheels with a pulley *v*, placed horizontally, and driving the tin drums which give motion to the spindles, fig. 78. To this barrel, G, are attached two cords or chains, one end of each of which is fastened to its circumference, and the other end of one is fixed to a movable nut worked by a screw along the radius of the quadrant, P, as less speed is required to be given to the barrel, and thence to the spindles, on account of the increasing size of the cop. The end of the other cord or chain is conducted over pulleys to the back of the mule, and to it a weight *d″*, is attached, which thus pulls at the external circumference of the barrel, and causes it to revolve as fast as the other cord or chain, connected with the quadrant, will allow. A weighted lever *h‴*, has one end resting on a stud fixed on the mule, and which moves in and out with the carriage, the other end of the weighted lever hangs by a chain on the fallers, and as the cop gets larger, the spindles winding on too fast, cause, by the tension of the yarn, the lever *h‴*, to descend a little, and press a strap against a fixed point; and as the car-

riage goes in it draws with it the strap, causing the nut, *w*, to go towards the circumference of the quadrant, and let off less cord so as to turn the barrel, *o*, fewer times during the going in of the carriage, and consequently the spindles revolve more slowly.

Description of the Self-actor Mule.

A self-actor is a mule in which not only the stretch is performed by the moving power, but also the backing off, the return of the carriage, and the winding-on of the yarn,—the operations succeeding each other without any interruption by certain disengagements of mechanism performed by the machine itself; so that attendants have nothing to do but to watch its movements, to piece the broken ends when the carriage begins to leave the roller-beam, and to stop it whenever the cop is completely formed, as indicated by the bell of the counter attached to the working geer. (A similar counter is attached to the automatic reel, p. 214.)

The self-acting mule of Messrs. Sharp, Roberts, and Co., differs from the fine spinning mule just described. It has its headstock advanced in the front of the roller-beam, near to the middle, and thus separates the spindles of the carriage into a right-hand and a left-hand series, and will serve to illustrate that class of mules. Fig. 77 exhibits a side view of the headstock, or a cross section of the mule close to the headstock, with the carriage shown, in the position of about the half-stretch.

Fig. 78 is a plan of the headstock, with part of the adjoining rollers on the right and left hand. In this plan, the top part of the headstock has been removed

to show the parts underneath; but it is shown in a separate plan, fig. 79.

Fig. 80 is a cross section of the mule, exhibiting its spinning parts.

Fig. 81 is a front view of the middle, being that part of the carriage which moves under the headstock, exhibiting a few spindles on each side.

Fig. 82 is the frame of the opposite side of the headstock, the fellow of that seen in Fig. 77.

Figs. 83 and 84 show a few parts of the machine in double scale, which will be referred to in the sequel.

A, A, A, fig. 77, is the frame of cast iron, to which, on each side of the headstock, is fixed the roller-beam, B, shown in section. C, C′, C″, are three steam-pulleys on a horizontal shaft, *a*. The pulley, C, fixed together with the wheels, 1, upon a boss, and running loose upon the shaft. C′, is fixed on the shaft; and C″, being of a smaller breadth, is a loose pulley. There are two straps, D and D′, to move these pulleys The first drives the pulleys, C and C′, together by covering one-half of each; but it slides during a certain period of each working on the pulley, C, alone, and continues to do so till a new stretch begins. At the same time the strap, D′, which moves more slowly, and in the contrary direction, runs for a few seconds on the pulley, C′, and immediately, thereafter, goes back to its loose pulley, C″. The pulley, C, which is always kept moving with uniform velocity, drives the apparatus by which the motions are changed, and brings also back the carriage towards the roller-beam, when all other motions are stopped. The said apparatus consists of the cam-shaft, *b*, with a pulley, *c*, called the friction-pulley, which has four grooved cavities, at equal distances, in its

Fig. 73.—Self-actor Mule. Plan of top of Head-stock.
Scale, three-fourths of an inch to the foot.

circumference, parallel to the axis, in any one of which the leather-covered pulley, *d*, fig. 72, may slide when revolving opposite to the groove. This pulley, *d*, is put in motion by wheel, 2, on its axis, driven from the wheel, 1, connected with the steam-pulley, C. When an edge of any one of the grooves of the pulley, *c*, by the action of a spring, is made to press against the leather-covered pulley, *d*, the latter will turn by friction, the pulley, *c*, through a quadrantal arc, till the shaft, *b*, is arrested by a catch, which prevents the further action of the spring, and makes the pulley, *d*, run in the concavity of the next groove. By disengaging the catch, the grooved pulley, *c*, will turn through another quadrant, and so in succession, making four different motions in one complete stretch. 3, is a pinion on the shaft, *a*, which drives by means of a carrier-wheel, 4, the wheel, 5, fixed upon the shaft, *e*; from this shaft motion is given to the shaft, *f*, connecting the front rollers of both sides of the

machine by means of the bevel-wheels, 6 and 7. On this shaft is also a pinion, 8, driving the wheel, 9, on the shaft with a drum, E, which draws the carriage out by means of a rope, fig. 78. The rollers are stopped by the machine pushing the bevel-wheel, 7, out of geer with, 6, drawing the coupling ends, *h*, from the pinion, 8, making this loose on the shaft, *f*, and at the same time pushing into geer the little bevel-wheel, 10, with the wheel, 11, whence the drum, E, now derives its motion. The wheel, 10, is driven by a strap going from the little pulley, *m*, on the shaft, *e*, to the larger pulley, *l*, on the shaft, *i*, thus giving a rather slow motion to the drum, E, and to the mule-carriage. From the front roller-shaft, motion is given in the usual way to the back roller-shaft by carrier-wheels; the carrier-shaft, *n*, serving for the rollers on both sides of the machine.

F, is a twofold spiral scroll, moving with a shaft in bearings of the frame, A, seen in figs. 77 and 78. To the smaller diameters of the scrolls are attached ropes going round the spirals, and thence they go to be fixed, after a few turns, the one on the drum, E, and the other on the guide-barrel, G. Two other ropes are attached to these two barrels, E and G, having their other ends fixed to two small barrels, *o* and *p*, at the carriage, H, fig. 77, which ropes can be tightened by turning the ratchet-wheels on the axes of the barrels, which are secured by clicks. The spiral scroll, F, has nothing to do in the bringing out of the carriage, which is performed by the revolving drum, E. This, however, being disengaged by shifting the wheel, 10, out of geer with 11, the carriage stops till it is to be returned, when the pinion, 12, is thrown in geer with the bevel-wheel, 13,

which acts upon the shaft of the scroll, F. This now moves the carriage, first with an increasing speed, and then with a speed decreasing, as it approaches the roller-beam, the drawing out ropes remaining equally stretched, since the scroll gives off in one direction as much rope as it takes up in another. The pinion, 12, is fixed upon the shaft, *q*, which is constantly revolving, (although not shifted in geer with 13,) being driven by the wheel, 14, which receives its motion from the carrier-wheel, 15, fig. 79, fixed with 16, upon

Fig. 80.—Self-actor Mule. Cross Section of the spinning parts.
Scale, three-fourths of an inch to the foot.

the shaft, *r*. The wheel, 16, gets its motion from the wheel, 1, which drives also the friction-pulley, *d*.

We shall now describe the driving parts in the carriage: *s* is an inclined shaft, standing parallel to the axis of the drums, K, fig. 80, from which the wharves of the spindles are turned by cords. On the shaft, *s*, is the double-grooved pulley, I, from which the drums, K, on the left and right-hand sides of the carriage, are driven by bands, as usual. On the under end of the shaft, *s*, is a bevel-wheel, 17, which is shifted in geer, either with the bevel-wheels 18 or 19, fig. 81. The wheel 18 is on the same shaft with a double-band pulley, L (77 and 81), which is driven by an endless band from the pulley, M, fixed on the principal shaft, *e*, and which is called the twist-pulley. The endless band comes from the twist-pulley, M, over the two guide-pulleys, *t* and *u*, seen in plan, fig. 78, and partly in 77—one end of this band going over the guide-pulley, N, and round the driving-pulley, L; then back round the guide-pulley again, and once more over the pulley, L: convolutions intended to increase the friction between the band and pulley, so as to effect the rotation of the spindles. The endless band goes thereafter round the horizontal tightening pulley, *v*, and thence back over the other guide-pulley, *t*, up to the twist-pulley, M. *See* fig. 81.

After the backing-off is performed, the shaft, *s*, is now shifted with its bevel-wheel, 17, in geer with the wheel, 19, on whose shaft is a wheel, 20, which is moved by another wheel, 21, fixed on the shaft of the barrel, O, or winding-on drum, which has grooves for receiving the convolutions of a chain attached to it. The other end of the chain is fixed to a point, *w*, of the apparatus,

P, fig. 77, to be presently described. The carriage, in moving backwards to the roller-beam, causes therefore the drum, O, to revolve as the chain pulls it round, its other end being fixed at the point, *w*. Thus, the shaft, *s*, revolves slowly, being set in motion by means of the train of wheel-work, 21, 20, 19, and 17, and which, during the going in of the carriage, makes the spindles to revolve, and by the depression of the faller, to wind on the yarn. P is a toothed quadrant, turning freely on a centre, *x*. It has a grooved arm, *y*, in front of which is a screw, bearing on its central end a little bevel-wheel, 22, in geer with another, 23, turning with a little pulley, *z*, on an axis. In the groove of the said arm slides a nut, *w*, being the point to which the end of the above chain is attached, moving gradually to the end of the screw by turning the pulley, *z*, and consequently the bevel-wheels, 23 and 22, the last of which is fixed upon the screw, *y*. This qua-

Fig. 81.—Self-actor Mule. Front View of the middle of the carriage. Scale, three-fourths of an inch to the foot.

drant moves through one-fourth of a circle during the going out of the carriage, being in geer with the pinion, 24, on the shaft of the guide-barrel G, round which the ropes pass which take out the carriage. Thereafter the scroll, F, moving back the carriage with a varying velocity, gives, by the pinion 24, a corresponding returning motion to the said quadrant, by which means the nut, *w*, is caused also to describe a quadrant of a circle of greater or less diameter, according to the point of the arm-radius, *y*, to which it has been screwed by the bevel-wheels, 22 and 23. By this action, the drum, O, does not turn in proportion to the advance of the carriage; the point, *w*, to which the end of the chain of that drum is attached following the motion of the carriage, in the proportion of the cosines of the arcs through which the quadrant, P, has turned. The turning of the drum, O, is thereby increased as the said cosines diminish, and therefore turns the spindle faster as the carriage approaches the roller-beam, the faller guiding the threads gradually upon the thinner diameter of the cop already made. In the beginning of building the cop, the nut, *w*, is nearest to the centre of the quadrant, P, and may then be considered as a fixed point for the chain, causing therefore the spindles to turn with the carriage during its going in, as represented above. During the making of the double-cone foundation of the cop, the nut, *w*, is moved gradually towards the extremity of the arm, *y*, thus describing increasing quadrantal arcs, and thereby causing the spindles to turn at each stretch more slowly at the beginning, and more quickly towards the end, of the winding-on, the faller beginning the winding-on each time at a higher point of the spindle.

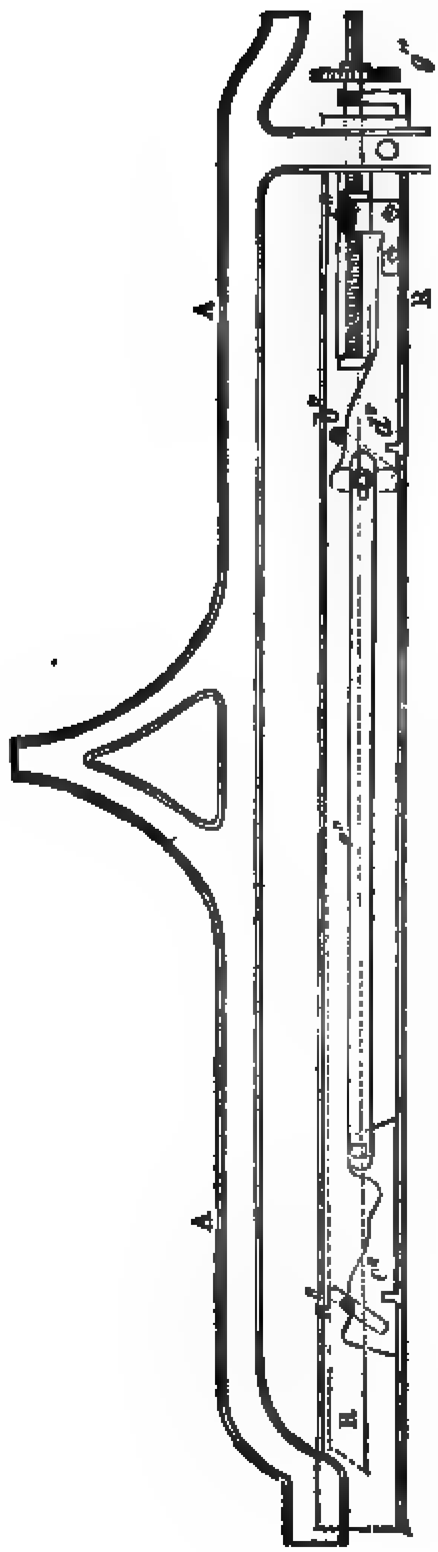


Fig. 83.—Frame of the opposite side of the Headstock to fig. 77.
Scale, three-fourths of an inch to the foot.

When the double cone is made, the winding-on, guided by the quadrant, P, remains constant, as the nut, *w*, does not move any more while the faller, after each stretch, continues to lay on the winding from a higher point of the spindle. The motion to the screw, *y*, is given at each stretch in the following way:—over the little pulley, *z*, fig. 77, and over the guide-pulley, *a′*, fixed to the frame, figs. 77 and 78, is an endless

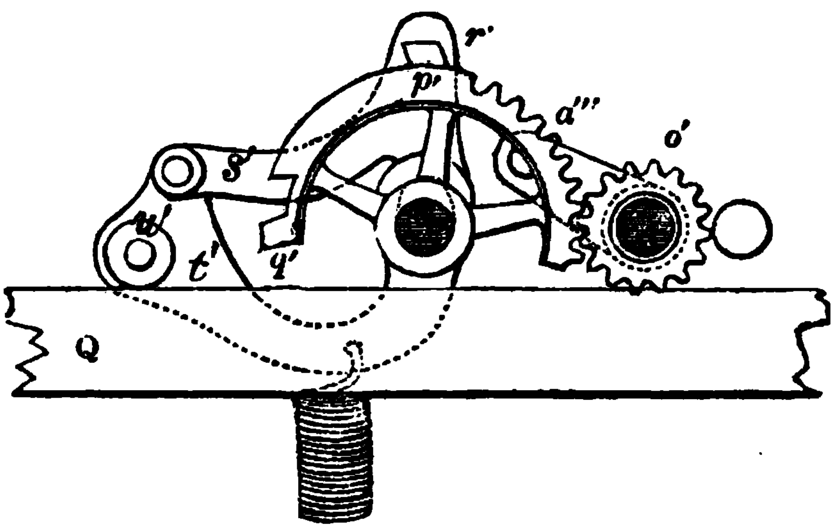


Fig. 83.—Details of the Self-actor. Scale, one inch and a half to the foot.

strap, a certain length of which is moved during the going back of the carriage in forming the double-cone foundation of the cop. *b′* is a lever, connected with the faller-arm, C′, by a chain, and which when the faller sinks, presses upon the said strap, and pinches it again to the plate, *d′* (fig. 81), whereby it is fixed by the returning carriage, and drawn along with it, till the faller, *c′*, rises again, and lifts the weight of the pinching lever, *b′*, from the plate. After the double cone is made, the faller no longer descends so low as to permit the lever, *b′*, to press upon the strap, after which the nut, *w*, is no further moved outwards; and thenceforth the cop continues to be built by winding on uniform conical surfaces of yarn upon the top cone, *a*, *b*, *d*, of the foundation, as shown by dotted lines in

plate V. fig. 3, the faller at each stretch descending less and less, and consequently beginning the winding-on at successively higher points.

On the carriage, figs. 80 and 81, are two shafts, *e′* and *f′*, running the whole length of the carriage, the first of which is the faller shaft, and the second the counterfaller shaft, which latter is here put in front of the carriage. On either side of the carriage, both are moved by small arms attached to them, and by connecting rods joined to arms, *i′* and *k′*, fixed on the ends of the horizontal shafts, *l′* and *m′*. The faller shaft, *e*, is always kept up by several spiral springs working on arms attached to it, unless it is depressed during the winding-on action of the machine. On the counterfaller shaft, *f′*, are several segments, from which are suspended by chains, weights, *n′*, which are directly proportional to the number of threads, and inversely to the fineness of the yarn—(*see* instructions, p. 202) which serve to support the threads during their winding on the spindles—a point explained with regard to the former hand-mule. The faller shafts *e′*, *e′*, on each side of the machine, are depressed

Fig. 81.—Details of the Self-actor. Scale, one inch and a half to the foot.

and raised in the following way. On the shaft belonging to the left side of the carriage is fixed a small pinion, o', which is in geer with a toothed segment, p', the shaft of which rests in bearings on the carriage, as shown in fig. 77. These parts are represented in double scale, figs. 83 and 84. It should be observed that the toothed segment, p', has one portion smooth, at whose end is a notch, q', into which, by turning the segment, which is loose on its shaft, a catch, r, may fall. This catch is fixed upon a curved arm, s', which embraces the shaft of the segment, and is thus permitted to move up and down with the catch, r'. Another curved arm, t', turns loosely round the shaft of the segment, and is connected by a link to the arm, s', and has at its end a roller, u', with which it is pressed, by a spiral spring, and slides, during the motions of the carriage, on a long rail, Q, which is fixed to the frame of the headstock, fig. 82, opposite, to that represented in fig. 77.

In fig. 82, this frame is shown with the rail, Q, in dotted lines behind. This rail has two pins, a'' and b'', going through the slots in the frame piece, R, which rest upon two plates, c'' and d'', called the *shaper*-plates, because they define the shape of the cop, and are connected with each other by the bar, e''. The shaper-plate, d'', has a nut, f'', in which a screw works, bearing on its end a ratchet-wheel, g'', one or two teeth of which are moved by a click from the carriage, at the end of each of its comings out. Thus the shaper-plates, c'' and d'', are gradually shifted, and the rail, Q, at the back of the frame piece, R, is permitted to sink a little, so as to make the roller, u, (figs. 83 and 84) run lower upon its rail, Q,

during the motions of the carriage. When the faller is depressed, which is at the time when the carriage begins its going in, the segment, p' is turned, and the catch, r', falling into the notch, q', must now follow the action of the sliding-roller, u', on the rail, Q. The segment, p', now driving the pinion, o', which is attached to the faller-shaft of the left side of the carriage, will give to that shaft a regular rising motion, in proportion as the carriage approaches to the roller-beam, by being connected to the roller, u', which runs over the inclined rail, Q. The carriage having reached the end of its course, the arm, s', goes over a bar, v', seen in section in fig. 84, and is fixed to the frame, by which means the catch, r', is lifted from its notch, q' (fig. 83), and the fallers made to rise by the spiral springs attached to them. The same motion is transferred to the faller shaft, e', on the right-hand side of the carriage, by the horizontal shaft, l', to which both are connected by arms and connecting rods.

We have now to explain how all these motions are successively produced in the machine. b, fig. 77, is the shaft which, by certain disengagements, is permitted to revolve at each of four different periods, through a fourth part of a circle. On this shaft are the following guides and excentrics: h'', the guide for the fork of the strap, D, which is attached to the top end of the lever; i'', the guide for the other strap, D', which is shifted by the lever, k'', fig. 79, working in the bar, l'', on the end of which is fixed the fork for the said strap. m'' is an excentric by which the bevel-wheel, 7, and the coupling clutch, h, are shifted out of geer, whilst the wheel, 10, is brought in geer with 11. The lever which carries

the bearing of the shaft, *i*, and shift-wheel, 10, into geer with 11, is connected with the lever, *n''*, fig. 77, working in the coupling, *h*, fig. 78, and is moved by the excentric, *m''*, by a hook which, being subsequently lifted, makes also the wheel, 10, to fall out of geer with 1; *o''* is a finger (seen best in fig. 79), by which the quantity of twist is regulated, and which keeps the shaft, *b*, from turning a fourth part of a revolution, till a notch in the plate, *p''*, allows that finger to strike through. The shaft is afterwards arrested in another way.

The plate, *p''*, is fixed on a shaft with wheel 25, which is driven by a worm at the end of the principal shaft, *a*, and may be varied in diameter, according to the quantity of twist the yarn is to have—(*see* figs. 77, 79). *q''* is another excentric by which the wheel, 12, is shifted in geer with 13, by means of the bell-crank lever, *r''*, at the end of which is the bearing of the shaft *q*.

s'' is a plate on the shaft *b*, having on one end four pins, against which a spring presses, *t''*, so as to bring the friction-pulley, *c*, in contact with the pulley, *d*, and thus to make it turn through a quadrant. On the other side of the said plate, *s''*, are three square escapement pieces, against which the end of a rod, *u''*, presses, connected with the end of the horizontal balance lever, S. By either depressing or lifting this lever, the rod, *u''*, is moved from one of the catches on the plate, *s''*, by which it revolves through a quadrant, as has been said, and is then caught by the next escapement on the plate, *s''*.

In the going out of the carriage, let us suppose the strap, D, to be driving both the pulleys, C and C', and the strap, D', to be on the loose pulley, C.'' The

rollers are turned by the shaft, *e*, and the carriage moved by the drum, E, getting motion by the wheels, 8 and 9, fig. 78. The twist is given from the pulley, M, driving the pulley, L; and by means of the wheel, 18, the wheel, 17, on the shaft, *s*, which is now in geer with it. The carriage coming near the end of its course, lifts a catch from a latch (*see* dotted lines, fig. 77) of the lever, S, which sinks, therefore, a little at S, and is caught by a second catch, which is connected by a rod, *v''*, to a lever, T, the latter resting on the boss of the curved arm, *s'* (*see* figs. 83 and 84, where that lever is represented in section).

By the falling of the end, S, of the balance lever, the rod, *u''*, has moved from one of the escapements of the plate, *s''*, and after the shaft, *b*, has made a quadrantal motion, it is arrested by the finger, *o''*, striking against the plate, *p''*; by this means the excentric, *m''*, on the shaft, *b*, has disconnected the coupling, *h*, fig. 78. The rollers are thus set at rest, while the carriage moves a little longer, but very slowly, being driven by the shaft, *i*, which is put in geer by the wheel 10 with 11. The carriage having arrived at the end of its course, strikes against a rod, not seen in the figures, detaching the click with which, by the lever *n''*, the wheel 10 was shifted into 11, thus setting at rest those parts which gave motion to the carriage. The twisting motion, however, is continued till the principal shaft, *a'*, has turned the wheel 25 so far round, that the finger, *o''*, can strike through the notch in the plate, *p''* (*see* upper part of fig. 77). The shaft, *b*, goes on to revolve through a second quadrant, and is now caught by the rod, *u''*, at one of the catches upon the plate, *s''*. By this quadrantal

motion the straps are shifted; D moves to the pulley C alone, and D′, which goes much slower, and in an opposite direction, is shifted to the pulley C′, which is fixed on the shaft of the twist-pulley, M. The latter is, therefore, now turning in the contrary direction, and giving a like motion to the spindles, thus backing off the coils of the yarn from the noses of the spindles. At the same time, however, a ratchet-wheel, *w″*, on the slant shaft, *s′* (in the carriage), turns by a click, *x″*, a plate connected with a spiral piece, *y″*, to which is attached the end of a chain, which passes over the two guide-pulleys, *z″*, to an arm, *a‴* (seen above, H), fixed upon the same shaft with the pinion, *o′*, figs. 77 and 84.

By the reverse motion of the shaft, *s*, therefore, the faller is depressed till a catch, *r′*, falls in the notch, *q′*, of the segment, *p′*. After which the faller follows the motion given to the roller, *u′*, by its sliding on the rail, Q. At the time, however, that the catch falls into the notch, the lever, T, which had been resting upon the boss of the curved arm, *s′*, falls also, and takes away the catch which had suspended the latch of the end, S′, of the balance lever, and makes this end to fall a second time, after which the rod, *u″*, lets another detent of plate, *s″*, escape, and causes the shaft, *b*, to revolve through the third quadrant, by which the straps, D and D′, are brought back to their former positions. Meanwhile the shaft, *s*, is shifted with its wheel 17 into geer with 19, as will presently be described, and the excentric, *q″* (fig. 77), has shifted the wheel 12 into geer with 13, which is fixed on a shaft with the scroll, F, by which the carriage is now returned towards the roller-beam, whilst the winding-on is performed by the drum, O (fig. 81),

turned by the chain attached to the nut, *w*, at the quadrant, P, fig. 77. Round the said drum there are a few coils of a rope, which passes over the two pulleys, b''' and c''' (fig. 79), and suspends a weight, d''', in order to keep the chain tight upon the drum, O.

When the carriage comes home to its place near the roller-beam, it presses down the end, S, fig. 77, of the balance-beam, and makes the rod, u'', to fall off from the third escapement of plate s'', after which the shaft *b* turns through the fourth quadrant. By this motion the excentric, q'', shifts the wheel 12, out of geer with 13, while the excentric, m'', sets the rollers in geer by the coupling-box, *h*, and of course also the drum, E, which moves out the carriage by the wheels 8 and 9. The bar, t', fitted to the frame (fig. 78) has now lifted the catch, r', out of the notch, q', in the segment, p', and thus has disengaged the faller shaft. Finally, the shaft, *s*, fig. 81. is shifted with its wheel 17, into geer with 18, to give twist again to the yarn spun during the next stretch of the carriage. It remains only to mention how this shifting of the shaft, *s*, is performed at the moment of the carriage going in and out. The step-bearing of the said shaft is fixed on the end of a bell-crank lever, e''' (bottom of fig. 77), the other end of which is connected with an arm, f''', on a shaft, g''', fig. 81, upon which shaft is a kind of a balance lever, h''', i''' (fig. 77), which slides when the carriage arrives at the two ends of its course, under rollers attached to the large radial weights U and V (fig. 77), which thus presses on that one of the arms, h''' or i''', which is just arrested by a detent or click, and keeps the wheel 17 in geer with either wheel 18 or 19. When the carriage is drawn out, and the wheel 17 is still in

geer with 18, the arm, h''', is suspended, and remains so till by the falling of the lever, T, the balance-lever, S, makes its second fall, and disengages the click by which the arm h''', was suspended, but is now depressed by the radial weight, whilst the other arm, i''', is now caught by another click. On the contrary when the carriage arrives near the roller-beam, at the same time that it depresses the balance-beam, S', and changes the motion, the click which keeps the arm, i''', suspended, is also disengaged, and the radial weight, V, presses down the arm, i''', whilst h''' is caught in its click, and keeps the wheel, 17, in geer with wheel, 18.

k''' is a detent or click, in which the arm, k', is caught. This is connected with the counter-faller shaft; when the carriage is going out, the arm, k', has on its end a roller which glides at the beginning of the course of the carriage, over an inclined plane, X, fixed on the floor, and lifts the arm, k', to be laid hold of by the catch k'''. When, however, the faller becomes depressed at the going in of the carriage, the finger, e''', attached to the arm, i', (fig. 74, near the left-hand wheel,) disengages the arm, k', from the catch, k''', and causes the counter-faller to react against the tension of the threads.

William Strutt, Esq., of Derby, F.R.S., a gentleman eminent for scientific knowledge and mechanical ingenuity, deserves to be recorded as the first contriver of a mule altogether automatic. In a memoir of the father, his enlightened son, Edward Strutt, Esq., M.P. for Derby, says, "Among his other inventions and improvements, we may mention a self-acting mule for the spinning of cotton, invented more than forty years

ago (before the year 1790); but we believe the inferior workmanship of that day prevented the success of an invention, which all the skill and improvement in the construction of machinery in the present day has barely accomplished." Mr. Strutt died in 1830, and the memoir of filial piety was published soon thereafter in a periodical journal.

Sketch of the Origin, Progress, and present State of the Spinning Machine, termed "the Self-acting Mule," by an eminent Factory Engineer.

The invention of this now important machine may, in a great measure, be attributed to the injurious effects resulting from turn-outs, and other acts of insubordination of work-people, which have, from time to time, led to the invention of machinery, as a substitute for, or in reduction of, the manual labour by which various operations were performed.

In working the common, or as it is, for the sake of distinction, now termed, the "hand-mule," various persons are employed to perform different portions of the work; viz., the "spinner," who directs the general operation of the machine, gives to the yarn a suitable degree of twist during the spinning, and, when spun, winds the yarn in a certain form round the spindle to make what is termed a "cop;" one or more "piecers" to join the threads which break during the spinning, and to remove the cops, when formed, from the spindles; a "creel-filler" to place the "rovings" from which the yarn is to be spun, in a part of the machine termed the "creel;" and a "cleaner," or "scavenger," to remove the waste cotton, termed "fly," which accu-

mulates during the spinning, and to clean the machine generally. The "spinner" being the principal person of the set thus employed, and, in most instances, an adult; the others being subordinate to him, and always young persons, or children; the set, thus arranged, working one pair of mules.

The "hand-mule" was invented about the year 1780, and from its importance in producing a peculiar kind of yarn, the use of it extended with great rapidity; and the demand thereby created for the labour of persons to work the machines, enabled the "spinner" to command a much higher rate of wages than was paid to artisans in general.

Notwithstanding this superior remuneration, the proprietors of cotton-mills were, for many years, subject to great disarrangement of business, and consequent loss, from the frequent turn-outs and other acts of insubordination of the "spinners;" by which acts, not only were their assistants thrown out of employ, but also in respect of each "spinner," three or four other persons employed upon machines required to prepare the cotton previous to being spun; all of whom, in by far the greatest number of instances, were reluctantly compelled to cease working, the product of their labour not being required whilst the "spinner" refused to work.

The injurious effects resulting from these tyrannical proceedings on the part of the "spinners," who, from their ample pecuniary resources, were able to continue them for long periods, naturally led to an anxious desire on the part of the proprietors of cotton-mills, that some means should be devised to enable them to dispense with the labour of the "spinners," who, by their

refractory conduct, inflicted so much injury on the interests of their employers, and, at the same time, caused so much distress to many of their fellow work-people.

The attention of spinners and mechanicians being thus directed to the subject during the last twenty or twenty-five years, many attempts have been made in this and other countries to invent mechanism which would dispense with the labour of the "spinner," or render the mule what is termed "self-acting," that is, by steam or other power, not manual, to cause the mule to go through the whole of its required movements to spin the yarn, retaining only the subordinate persons to piece the threads, fill the creels, clean the mule, &c. &c.

Of the various attempts made to accomplish an object of so much importance to that great branch of business, cotton spinning, the inventions of the following parties only have been put into operation beyond the purposes of experiment; viz., Messrs. Eaton, formerly of Manchester; Mr. De Jongh, formerly of Warrington; Mr. Buchanan, of the Catrine works, Scotland; Mr. Brewster, of America; Mr. Roberts, a partner in the firm of Sharp, Roberts, and Co., of Manchester; and Mr. Knowles, of Manchester.

Of the self-acting mules invented by Messrs. Eaton, ten or twelve only were put in operation in Manchester, and at Wiln, in Derbyshire, and a few in France; but from their great complexity and limited production, the whole were soon relinquished, except four at Wiln.

Mr. de Jongh obtained two patents for self-acting mules, and put twelve of them in operation in a mill

at Warrington, of which he was part proprietor, but with an unsuccessful result, and they were consequently given up.

Mr. Buchanan, it is reported, has several mules, partly or entirely self-acting, at work in Scotland, but the principle of their construction has not been made public.

Of Mr. Brewster's self-acting mule nothing is known beyond the report that there are mules at work in America, of his invention, for spinning wool.

The first approximation to a successful accomplishment of the objects in view was an invention of a self-acting mule, by Mr. Roberts, one of the principal points of which was, the mode of governing the winding-on of the yarn into the form of a cop; the entire novelty and great ingenuity of which invention was universally admitted, and proved the main step to the final accomplishment of that object which had so long been a desideratum. For that invention a patent was obtained in 1825, and several headstocks upon the principle were made, which are still working successfully; but, from a combination of various causes, the invention was not extensively adopted.

In 1827, Mr. De Jongh obtained a third patent for a self-acting mule; upon which plan, with the addition of part of Mr. Roberts's invention, which was found to be essential, about thirty mules were made, part to spin cotton, and part woollen yarn. The greater part of these are continued at work, but, it is reported, with only a moderate degree of success.

In 1830, Mr. Roberts obtained a patent for the invention of certain improvements; and, by a combination of both his inventions, he produced a self-acting

mule, which is generally admitted to have exceeded the most sanguine expectations, and which has been extensively adopted.

In 1831, Mr. Knowles, of Manchester, supported by the Oxford Road Twist Company, to whom he was manager, obtained a patent for a self-acting mule. On the enrolment of his specification, however, it was discovered that he had infringed both of Mr. Roberts's patents. Application was consequently made to the Court of Chancery for an injunction, which was immediately granted; and on a motion to dissolve the injunction, it was refused. Subsequently, in order to avoid an action at law, Mr. Knowles and the Oxford Road Twist Company consented to the injunction being perpetuated, with costs; when permission was granted by Messrs. Sharp, Roberts, and Co., for Mr. Knowles's mule to be used in the mills of the Oxford Road Twist Company *only*, on condition of their paying a consideration for using any part of Mr. Roberts's invention, should they do so.

Such is a short sketch of the origin and progress of self-acting mules, up to the year 1830; since that time, the patent mule of Messrs. Sharp, Roberts, and Co. has been extensively adopted, there being at the present time (Dec. 1834) in operation, in upwards of 60 mills, between 300,000 and 400,000 spindles, besides extensive orders in course of execution. It may be proper to observe, the adoption of the mechanism to render mules self-acting does not involve a sacrifice of the whole of the hand-mule, but merely that part of it termed the headstock, being in value about one-fifth of the entire mule, the self-acting mechanism being contained in the headstock, which is adapted to

be applied to the other parts of a mule, as the roller-carriage spindles are termed the body of the mule.

In considering the advantages resulting to the proprietors of cotton-mills from the use of self-acting mules, it may be stated that, although the only, or at any rate the principal benefit anticipated, was the saving of the high wages paid to the hand "spinner," and a release from the domination which he had for so long a period exercised over his employers and his fellow work-people, it soon became manifest that other and very important advantages were connected with the use of the machine.

The various advantages attending the use of self-acting mule headstocks, were enumerated in a statement submitted by Messrs. Sharp, Roberts, and Co. to the proprietors of cotton-mills, of the principal points in which the following is a copy:—

"First, the advantages connected with spinning.

"The saving of a 'spinner's' wages to each pair of mules, piecers only being required, one overlooker being sufficient to manage six or eight pair of mules or upwards.

"The production of a greater quantity of yarn, in the ratio of 15 to 20 per cent., or upwards.

"The yarn possesses a more uniform degree of twist, and is not liable to be strained during the spinning, or in winding-on, to form the cop; consequently fewer threads are broken in those processes, and the yarn, from having fewer piecings, is more regular.

"The cops are made firmer, of better shape, and with undeviating uniformity; and from being more regularly and firmly wound, contain from one-third to one-half more yarn than cops of equal bulk wound by

hand; they are consequently less liable to injury in packing or in carriage, and the expense of packages and freight (when charged by measurement), is considerably reduced.

"From the cops being more regularly and firmly wound, combined with their superior formation, the yarn intended for warps less frequently breaks in winding or reeling, consequently there is a considerable saving of waste in those processes.

"Secondly, the advantages connected with weaving.

"The cops being more regularly and firmly wound, the yarn, when used as weft, seldom breaks in weaving; and as the cops also contain a greater quantity of weft, there are fewer bottoms, consequently there is a very material saving of waste in the process of weaving.

From those combined circumstances, the quality of the cloth is improved, by being more free from defects, caused by the breakage of the warp or weft, as well as the selvages being more regular.

"The looms can also be worked at greater speed, and, from there being fewer stoppages, a greater quantity of cloth may be produced.

"That the advantages thus enumerated, as derivable from the use of self-acting mules, have not been over-rated, but in many instances have been considerably exceeded, the author, by extensive personal inquiry and observation, has had ample opportunity of proving, &c. &c.

"Statement of the quantity of yarn produced on Messrs. Sharp, Roberts, and Co.'s self-acting mules in twelve working hours, including the usual stoppages

connected with spinning, estimated on the average of upwards of twenty mills :—

No. of Yarn.	No. of Twist.	No. of Weft.
16	. $4\frac{1}{2}$ hanks	. $4\frac{7}{8}$ hanks per spindle.
24	. $4\frac{1}{4}$ „	. $4\frac{5}{8}$ „
32	. 4 „	. $4\frac{3}{8}$ „
40	. $3\frac{3}{4}$ „	. $4\frac{1}{8}$ „

"Of the intermediate numbers the quantities are proportionate.

"Dec. 23, 1834."

Results of trials made by Messrs. Sharp, Roberts, and Co., at various mills, to ascertain the comparative power required to work self-acting mules, in reference to hand-mules, during the spinning up to the period of backing off.

The mode adopted to make the trials was as follows, viz. :—

A force, indicated by weight in pounds, was applied to the strap working upon the driving-pulley of the respective mules, sufficient to maintain the motion of the mule whilst spinning, which weight, being multiplied by the length of strap delivered by each revolution of the pulley, and again by the number of revolutions made by the pulley whilst spinning, gave the total force in pounds, applied to the respective mules whilst spinning; for instance, suppose a mule to be driven by a pulley 12 inches diameter (3·14 ft. in circumference), such pulley making 58 revolutions during the spinning as above, and that it required a force equal to 30 lbs. weight to maintain the motion of the mule; then 30 lbs. × 3·14 feet circumference of pulley × 58 revolutions in spinning = 5,463 lbs. of force employed during the spinning to the period of backing off.

Particulars of the trials referred to, and their results :—

At what Mill, and the description of Mule.	kind of Yarn.	Diameter of [illegible] or Rim-wh[illegible]	Revolutions [illegible] ley or Rim-[illegible]	Required Po[illegible] Motion.	employed in Spinning.
Messrs. Birley & Kirk.	Weft.	Ins.		lbs.	lbs.
Self-acting Mule, 360 sps.	30 to 34	12	58	30	5,463
*Hand-Mule, 180 sps. . .	do.	[illegible]	36	26	3,669 × 2 = 7,338
Messrs. Leech and Vandrey	Twist.				
†Self-acting Mule, 324 sps.	36	[illegible]	70	36	7,912
Hand-Mules, 324 sps. . .	36	29	58	16½	7,273
Messrs. Duckworth & Co.	Twist.				
Self-acting Mule, 324 sps.	40	12	62	33	6,421
Hand-Mule, 324 sps. . .	40	47	36	15½	6,646

* The trial was disadvantageous for the hand-mules, being two for 360 spindles.

† The trial was disadvantageous for the self-acting mules, being driven by a very short and tight vertical strap, the hand-mule having a long, horizontal strap.

Tables and Instructions referring to Sharp, Roberts, and Co's Self-Acting Mule, showing the Speed to be given to the Twist-pulley for different counts of Yarn; the Wheels and Pulleys requiring to be changed in varying the count; the mode of calculating such changes, &c.

NOTE.—The figures placed between parentheses, after the name of any part of the machine, refer to the sketch of such part, in the set of plates supplied to parties using the self-acting headstock. The letters P. L. signify the pitch line of the part referred to.

Twist-Pulley (No. 4.) M, figs. 77, 79.

In the twist-pulley are five grooves, of different diameters, by which the speed of the spindles may be varied to a certain extent, without changing the strap-pulleys in the driving apparatus over the headstock.

The dimensions of the intermediate double-grooved pulleys (No. 220 and 223), I and L, fig. 81, which carry the band to communicate motion from the twist-pulley to the drums, are so arranged as to cause the revolutions of the twist-pulley and the spindles to be nearly in the ratio of the pitch-line diameters of the twist-pulley (taken at ½ inch more than the bottom of the groove,) to the pitch-line diameter of the warves of the spindles (taken at $\frac{1}{16}$ inch more than the bottom of the groove,) assuming that the face of the drum, and the bottom of the grooves for its band, are of equal diameters, or nearly so, as is generally the case; but for the sake of accuracy in calculating the speed of the spindles, it is desirable to ascertain, by actual experiment, their relative speed with each of the five grooves of the twist-pulley.

Although the speed at which it is advisable that the spindles of mules should revolve, depends upon, and is regulated by, a variety of circumstances, yet the following is submitted as a table of speeds, for various counts of yarn, at which self-acting mules, of moderate size, and in good condition, have been proved to work effectively, when spinning from rovings of medium or fair quality. The table also exhibits the speeds at which the twist-pulley should revolve, so as to admit of all the various speeds of the spindles being produced, by placing the band in a suitable groove of the

pulley. The speeds in the table being arranged for mules of not exceeding 300 to 340 twist, or 350 to 400 weft spindles, for larger mules the twist-pulley should be speeded about 5 revolutions per minute slower, for about every 30 additional twist, or 40 weft spindles.

NOTE.—When it becomes requisite to increase or decrease the speed of the twist-pulley, the change is, in general, most easily effected in the fast and loose pulleys in the driving apparatus; and as the speeds stated in the table are intended for the *actual* speeds, in calculating, an allowance should be made for the slipping of straps, ranging from 5 to 7½ per cent.

TABLE of Speeds of Spindles, for spinning various counts of Yarn, Twist, and Weft; and the Speeds at which the Twist-pulley should revolve, to produce such Speeds of the Spindles.

No. of Yarn.	Speed for Twist.	Revolutions of Pulley.	Speed for Weft.	Revolutions of Pulley.
8	3,800	210 to 220	2,800	160 to 170
10	3,875	,,	2,900	,,
12	3,950	,,	3,000	,,
14	4,025	,,	3,100	,,
16	4,100	,,	3,200	,,
18	4,175	230 to 240	3,300	190 to 200
20	4,250	,,	3,400	,,
22	4,325	,,	3,500	,,
24	4,400	,,	3,600	,,
26	4,475	,,	3,700	,,
28	4,550	,,	3,800	,,
30	4,625	,,	3,900	,,
32	4,700	250 to 260	4,000	220 to 230
34	4,775	,,	4,100	,,
36	4,850	,,	4,200	,,
38	4,925	,,	4,300	,,
40	5,000	,,	4,400	,,
42	,,	,,	,,	,,
44	,,	,,	,,	,,
46	,,	,,	,,	,,
48	,,	,,	,,	,,
50	,,	,,	,,	,,
52	,,	,,	,,	,,
54	,,	,,	,,	,,

The foregoing table, as stated, refers to yarn of *medium* quality, and is intended only as a general guide, subject to certain modifications: for instance, for yarn spun from rovings of a *low* quality the speed of the twist-pulley may be decreased, or the band may be placed one or two grooves *lower* on the pulley than for rovings of *medium* quality; and for yarn spun from *superior* rovings, the band may be placed one groove higher than for rovings of *medium* quality; in either case, a suitable twist-wheel must be used to give the proper quantity of twist to the yarn. In equal cases, as to *count* and *quality* of yarn, when a variation in *quantity* of *twist* only is required, it is better to change the twist-wheel than to remove the band from the groove which gives the speed best suited to the quality of yarn.

The going-in, or putting-up of the carriage.

The going-in speed of the carriage should be adapted to the speed of the twist-pulley, and the size of the mule, which may be effected by varying the spur-wheels (No. 65 and 67.) *See* 15, and 14, fig. 51, p. 182.

TABLE of the relative Number of Teeth in the two going-in Spur-wheels (the total number being 57 teeth), to effect the putting-up of the carriage at a suitable Speed.

No. of Spindles in Mule.	Speeds of the Twist Pulley.							
	Not exceedg. 200 Revs.		Above 200, Not ex. 230		Above 230, Not ex. 260		Above 260 Revoltns.	
	Wheel. 65	Wheel. 67	Wheel. 65	Wheel. 67	Wheel. 65	Wheel. 67	Wheel. 65	Wheel. 67
	Teeth.	Teeth.	Teeth.	Teeth.	Teeth.	Teeth.	Teeth.	Teeth.
Not exceeding 360 twist, or 420 weft spindles.	29	28	28	29	27	30	26	31
Above 360 twist, or 420 weft spindles . .	28	29	27	30	26	31	25	32
Above 420 twist, or 480 weft spindles . .	27	30	26	31	25	32	24	33

For a variation of 20 revolutions per minute in the speed of the twist-pulley, a corresponding variation may be made in the putting-up of the carriage by an alteration of one tooth in each of the spur-wheels (No. 65 and 67.) 15 and 14, fig. 51.

Information required as data for calculating the changes which may be required in the following parts of a self-acting mule; viz.,—

The twist-wheel, (No. 34.) *See* 25, fig. 77.
The back-change wheel, (No. 26.)
The rack-pinion pulley, (No. 239.)
The shaper-wheel, (No. 159.)

1st.—The number of yarn to be spun, and whether twist or weft; and the desired diameter of the cop?

2d.—The number of turns of twist per inch, which the yarn should have, specifying the proportion of twist to be given during the draw, and at the head?

3d.—How much the carriage should gain on the rollers during the draw?

4th.—The diameter of the front roller?

5th.—The number of revolutions of the spindles for one of the twist-pulley, ascertained by experiment, with the band in the middle groove?

6th.—The number of teeth in the rack-pinion (No. 237?)

7th.—The number of teeth in the pinion (No. 23) on the twist-pulley shaft?

Tables connected with parts of the self-acting mule headstock, to facilitate the calculation of change-wheels, pulleys, &c.

TABLE of the Number of Revolutions made by Front Rollers of various diameters, in delivering various lengths of Yarn.

Delivery of Yarn. Inches.	Diameter and Circumference of Rollers.					
	7-8th Dia. 2·74 Circ.	15-16th Dia. 2·94 Circ.	1 Dia. 3·14 Circ.	1 1-16th Dia. 3·33 Circ.	1 1-8th Dia. 3·53 Circ.	1 1-4th Dia. 3·92 Circ.
50	18·24	17·	15·92	15·01	14·16	12·75
50½	18·43	17·17	16·08	15·16	14·30	12·88
51	18·61	17·34	16·24	15·31	14·44	13·01
51½	18·79	17·51	16·40	15·46	14.58	13·13
52	18·97	17·68	16·56	15·61	14·73	13·26
52½	19·16	17·85	16·71	15·76	14·87	13.39
53	19·34	18·02	16·87	15·91	15·01	13·52
53½	19·52	18·09	17·03	16·06	15·15	13·64
54	19·70	18·36	17·19	16·21	15·29	13·77
54½	19·89	18·53	17·35	16·36	15·43	13·90
55	20·07	18·70	17·51	16·51	15·58	14.03
55½	20·25	18·87	17·67	16·66	15·72	14·15
56	20·43	19·04	17·83	16·81	15·86	14·28
56½	20·62	19·21	17·99	16·96	16·	14·41
57	20·80	19·38	18·15	17·11	16·14	14·54
57½	20·98	19·55	18·31	17·26	16·28	14·66
58	21·16	19·72	18·47	17·41	16·43	14·79
58½	21·35	19·89	18·63	17·56	16·57	14·92
59	21·53	20·06	18·78	17·71	16·71	15·05
59½	21·71	20·23	18·94	17·86	16·85	15·17
60	21·89	20·40	19·10	18·01	16·99	15·30

TABLE of the Number of Revolutions made by Rack Pinions, of various Numbers of Teeth, in Stretches of various length.

Stretch. Inches.	16 Teeth. 1 rev. 3·30 in.	17 Teeth. 1 rev. 3·51 in.	18 Teeth. 1 rev. 3·72 in.	19 Teeth. 1 rev. 3·93 in.	20 Teeth. 1 rev. 4·14 in.	21 Teeth. 1 rev. 4·35 in.
55	16·66	15·66	14·78	13·99	13·28	12·64
57½	17·42	16·38	15·45	14·63	13·88	13·21
60	18·18	17·09	16·12	15·26	14·49	13·79

Front roller-shaft pulley (No. 82), whether for band or strap.
Pulley for band, P. L. diameter 5½ inches—P. L. circumference 17·27 in.
Pulley for strap, P. L. diameter 5¼ inches—P. L. circumference 16·48 in.

Rules for calculating the Wheels and Pulleys of the Headstock which require to be changed, in varying the count and quality of the Yarn.

1*st.*—*Twist-Wheel* (No. 34).

To find the proper twist-wheel to give to the yarn any required number of turns of twist per inch.

Multiply the number of inches in the total stretch or draw of the carriage by the required number of turns of twist per inch in the yarn; divide the product by the number of revolutions given to the spindles in one revolution of the twist-pulley, and the quotient will give the number of teeth for the twist-wheel.

Example: suppose,

The total stretch or draw of the carriage, 57½ inches,

The required number of turns of twist per inch, 21,

The ratio of the spindles to the twist-pulley 17·6 to 1,

Then, 57·5 inches $\times$ 21 twist $\div$ 17·6 ratio $=$ 68 teeth in the twist-wheel.

N.B.—The number of turns of twist per inch may be increased or reduced, either by varying the number of teeth in the twist-wheel, or by placing the band in a different groove of the twist-pulley, or by a union of the two modes, as the case may require.

The general pitch of the twist-wheel and the worm (No. 8), prepared for the headstock, will suffice for all counts of yarn from No. 10 to No. 50; but for higher counts than No. 50, a finer pitch will be required, the diameter of the twist-wheel being limited. For lower counts than No. 10, a double worm will be required.

2d.—*Back Change-Wheel* (No. 26).

To find the back change-wheel, that will admit of the required proportion of the total twist being given during the coming out of the carriage, and at the head.

Multiply the number of teeth in the pinion (No. 23), on the twist-pulley shaft, by the number of revolutions of that shaft required to give the proportion of twist during the coming out of the carriage;—divide the product by the number of revolutions of the front roller in delivering the yarn, and the quotient will give the number of teeth for the back change-wheel.

Example: suppose,

1st.—The total number of turns of twist per inch, 21; proportion in the coming out of the carriage, 16, at the head, 5.

2d.—The number of teeth in the pinion on the twist-pulley shaft, 18.

3d.—The revolutions of the twist-pulley shaft during the coming out of the carriage, 52; viz., the total revolutions of the shaft equal the number of teeth in the twist-wheel, say 58; and as 21 total twist : 16 required in coming out :: 68 total revolutions : 52 revolutions of the shaft in coming out.

4th.—The delivery of yarn 54 inches; the diameter of the front rollers 1 inch = circumference 3·14 inches; 54 inches $\div$ 3·14 = 17·22 revolutions of rollers in delivery.

Then, 18 back pinion $\times$ 52 revolutions of twist-pulley shaft $\div$ 17·22 revolutions of rollers = 54 teeth in the back change-wheel.

N.B.—By increasing or reducing the number of teeth in the back change-wheel, a greater or less pro-

portion of the total twist is given during the coming out of the carriage.

3d.—*Rack-Pinion Pulley* (No. 239).

To find the diameter of the rack-pinion pulley which will produce the required gain of the carriage upon the rollers during the coming out of the carriage.

Multiply the P. L. circumference of the front roller-shaft pulley (No. 82) by the number of revolutions of that pulley during the delivery of the rollers; to the product add the length, in inches, of the total stretch; then divide the sum by the number of revolutions of the rack-pinion during the total stretch, and the quotient will give the P. L. circumference of the rack-pinion pulley, from which the P. L. diameter may be found.

Example: suppose,

The total stretch $57\frac{1}{2}$ inches.

The gain of the carriage $3\frac{1}{2}$ inches.

The diameter of the front roller 1 inch = circumference 3·14 inches.

The P. L. diameter of the front roller-shaft pulley $5\frac{1}{2}$ inches = P. L. circumference 17·27 inches.

The number of teeth in the rack-pinion 18; advance on the rack in one revolution 3·72 inches.

1st.—57·5 inches stretch − $3\frac{1}{2}$ inches gain of carriage = 54 inches delivery of rollers ÷ 3·14 inches circumference of rollers = 17·22 revolutions of front roller-shaft pulley.

2d.—57·5 inches stretch ÷ 3·72 inches advance of rack-pinion in one revolution = 15·45 revolutions of pinion in stretch.

Then 17·27 P. L. circumference of pulley × 17.22

its revolutions + 57·5 inches stretch = 354·88 inches ÷ 15·45 revolutions of pinion = 22·96 inches P. L. circumference ÷ 3·14 = 7·3 inches P. L. diameter of rack-pinion pulley.

N.B.—In order that the diameter of the rack-pinion pulleys should not vary more than 1 inch, viz., from $6\frac{1}{2}$ to $7\frac{1}{2}$ inches, the number of teeth in the rack-pinion requires to be varied, according to the diameter of the front roller. The following scale will be a suitable one to produce any gain of the carriage upon the rollers, not exceeding 6 inches, viz.:—

For Rollers	$\frac{7}{8}$ *or* $\frac{15}{16}$	*in. diameter,*	*a Pinion of*	17	*Teeth.*
„	1 or $\frac{17}{16}$	„	„	18	„
„	$1\frac{1}{8}$ or $\frac{19}{16}$	„	„	19	„
„	$1\frac{1}{4}$	„	„	20	„

It may occasionally save calculation to note, that a reduction of $\frac{1}{8}$ inch in the diameter of the rack-pinion pulley, increases the gain of the carriage about 1 inch; and an increase of $\frac{1}{8}$ inch decreases the gain in a similar degree.

4th.—Shaper-Wheel (No. 159).

The number of teeth in the shaper-wheel will nearly correspond with the count of the yarn, to make a twist-cop of $1\frac{1}{4}$ inch diameter, or a weft-cop of 1 inch diameter (care being taken to use the proper copping-plates.)

To make a cop of greater diameter, use a wheel with a greater number of teeth; and to make one of less diameter, use a wheel with a less number of teeth. It may also be observed, that in counts of yarn below No. 24, it will be convenient to have a wheel which will admit of two, and in some cases three teeth being

taken at once, by which means a more minute increase or decrease in the diameter of the cop may be effected, than by one tooth only being taken.

5th.—Counter-Faller Weight (No. 272).

The quantum of weight to be applied to the counter-faller will depend on the number of spindles in the mule, the count and description of the yarn, and the degree of hardness of cop which the yarn will admit of, without injury to the quality.

As a general guide, however, faller weights may be used as follows, viz.:

On twist-mules, for every 100 spindles, 12 to 16 lbs.

On weft-mules, for every 100 spindles, 9 to 12 „

Low counts, of course, admitting of greater weight than fine counts. In cases where the relieving lever-weight (No. 285) is introduced, which, whilst the yarn is backed off, and the faller depressed, is caused not to act upon the counter-faller, but when those motions are performed, is caused to act upon it, during the winding-on of the yarn, by resting on a catch (No. 288) connected with one of the counter-faller coupling-links (No. 256) and the counter-faller arm (No. 271);—the proportion of weight so applied, should be from two-fifths to three-sevenths of the total weight acting upon the counter-faller; the remaining three-fifths, or four-sevenths, being suspended from the arm (No. 273) on the counter-faller shaft.

NOTE.—In the foregoing calculations with which a V grooved pulley is connected, the *pitch line* diameter is assumed at ½ inch more than the diameter at the *bottom of the groove*. In cases, therefore, where a band of such size may be used, as to cause the *pitch line* diameter to be greater or less than is assumed, there will be a corresponding variation between the *calculated* and the *actual* result, which must be allowed for.

The grinding of mule-spindles is performed upon an ordinary large grindstone, turning into a vertical plane, against the edge of which the spindle is pressed by a long cross-lever, carrying a wooden roller on its middle, which is made to bear against the side of the spindle, held tangentially to the face of the grindstone.

After having been forged at the anvil, the mule-spindles are hammered straight on a flat table of iron, and proved by suspending each horizontally between two points, and turning them round at a small distance from the table. The spindles are then ground and polished. They are finally pointed upon another grindstone.

For mule-spindles, both a coarse and a polishing grindstone are employed.

The spindles of bobbin-and-fly frames are turned on a lathe at the ends, and afterwards fixed to their flyers by a cross-pin.

The throstle-spindles, however, are screwed to the fly by a few threads formed at their points.

The flys of the throstles are polished by mutual attrition in a revolving barrel, containing shreds of leather—a process which occupies two or three days.

Spindles are tempered by being heated red hot in bundles of 6 dozen, or thereby, and then dipped perpendicularly into a stratum of water, only half an inch deep; the object being to harden merely their tips.

Mr. Whitworth, an eminent machine maker, in Manchester, obtained a patent in April, 1835, for certain modifications of the self-actor mule, in which he specifies several ingenious devices. The mechanism is designed, first, to traverse the carriage in and out by means of screws or worm-shafts, which are placed

so as to keep the carriage parallel to the drawing-rollers, and supersede squaring bands; secondly, to afford an improved manner of working the drums of a self-acting mule by geer; thirdly, better means of effecting the backing off; fourthly, a new mechanism for working the faller-wire in building the cops; and fifthly, an apparatus for winding the yarn on to the spindles. His mule is constructed upon the box-organ principle represented in plate V. For further details of this ingenious machine, we must refer our readers to the specification in "Newton's London Journal," for March, 1836, page 1.

SECTION IV.

Reeling into Hanks and Counting.

THE automatic reel employed for winding the yarn into measured lengths, called hanks, from the bobbins of the throstle or the cops of the mule, in order to prepare it for the general market, is a beautiful mechanism, as constructed in a modern cotton-mill.

The cops made on the mule being light and easily transported are not always reeled off, if they be destined for the shuttle, or the doubling-mill. But if their yarn be of the warp quality, it must be wound upon large bobbins suited to the warping-mill. These bobbins are filled with cop or throstle yarn, by being laid horizontally upon revolving carrier-pulleys or barrels, so that they may turn by mere friction, and wind on the thread from the cops or small bobbins set upright on skewers in an adjoining shelf or creel.

The machine represented in figs. 79 and 80 is employed for winding yarn or threads from bobbins into

regular hanks, 840 yards in length. It consists—1st, of a hexagon reel, one yard and a half in circumference; 2d, of a carriage, upon which the spindles or skewers are mounted that bear the bobbins. This carriage has a slow traverse motion parallel to the axis of the reel, for the proper distribution of the thread upon its surface. 3d, of the frame-work upon which the carriage traverses; and 4th, of the driving-geer or mechanism.

Fig. 79 is an end view, and fig. 80 a front view; the middle portion of the machine having been left out in the drawing, as being merely a repetition of the same parts. A A are two end iron framings, connected by two wooden cross-rails, *a*. B is the reel, consisting of six horizontal lathes or spars, made fast to arms which

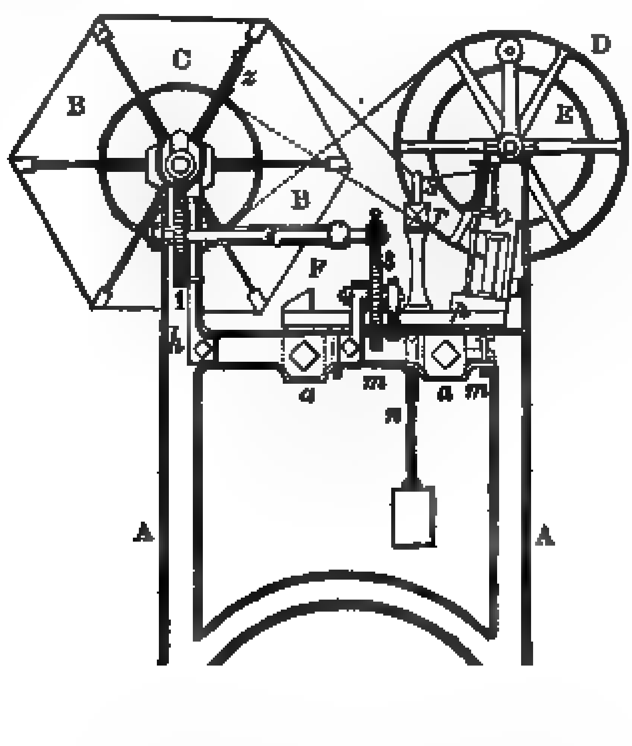


Fig. 79.—Automatic Reel, for winding and counting hanks. End view. Scale, three-fourths of an inch to the foot.

pass through the central wooden shaft *b*, fig. 80. The arm *z* of one of the six lathes is made of two pieces connected by a hinge-joint, round which this lath may be turned, to loosen the hank-coils, in order to remove them from the reel. During the winding, the arm is kept extended in a straight line by wire-hooks catching in eyes.

Fig. 90.—Automatic Reel. Front View. Scale, three-fourths of an inch to the foot.

Upon the other end of the machine, to that represented in fig. 79, a pulley, C, is fixed, upon the prolonged axis of the wooden shaft, *b*, exterior to the frame. This pulley is driven by a strap from the pulley D, upon a short iron shaft, which is either moved by the hand applied to the winch-handle *d* (fig. 80), or by a strap from the mill-shaft, passing over the usual outrigger fast and loose pulleys at E. *e* is the forked bar to serve as a guide to the strap. The attendant may move it when he pleases, by means of a horizontal geering-rod, *f*, which extends along the front of the machine, to give him the facility of acting on the straps at whatever point he may happen to be. If a thread chance to break, he shifts his rod to the left hand and stops the machine, by throwing the strap outwards upon the loose pulley.

Upon the other end of the central iron axis of the wooden shaft, *b*, there is a worm-screw, *g*, which drives the wheel, 1. In the circumference of this wheel there is a stud or pin, *c*, which, after each revolution of the reel, strikes against a bell-spring, *h*, and produces a jarring sound, announcing to the tenter that a certain measure of yarn is completed in the winding. At the right-hand end of the shaft, *i*, of the wheel, 1, is a small pinion, 2, driving the wheel, 3, to which a spiral plate, *k*, is fixed, which works against an iron bar, *l*, attached to the carriage that bears the bobbins. F F is the carriage which traverses upon rollers *m*, attached to the wooden-stretcher rails, *a*, *a*. Another roller, *n*, serves for putting a band over, which is fixed to the carriage, and suspends a weight for keeping the carriage in contact with the spiral plate, *k*.

o represents (fig. 79) the top bearing, and *p* the

under or step-bearing of the spindles. These are generally old ones removed from the mules. *q* are the bobbins made fast by pressure upon their respective spindles with which they revolve. In fig. 80, three bobbins are seen in their places, the other spindles are bare. *r*, is a wooden bar fixed upon the carriage, bearing glass hooks, *s*, at its top, for guiding the thread from the bobbins to the reel.

t is a ring at the end of a cord, *u* (fig. 80), suspended from a pulley at the ceiling; the other end of the cord goes over a second pulley, at a convenient place in the apartment for hanging on a counter-weight.

As soon as the winding on of the hanks is completed, and they have been separately tied round with a string to separate and distinguish them, the hooks which keep the arm *z*, of the reel extended are loosened, the lathe, or rod, is turned inwards, all the hanks are slid by hand towards the worm-screw end of the reel, which is then lifted up out of its bearings. The tenter (a young woman) pulls down the rope, *u*, and slips the ring *t*, upon the hook, *v*, attached to the wooden shaft of the reel, which will thus continue suspended above its bearing at the full end, till the hanks are taken off it. The reel is now lowered, the ring, *t*, is unhooked, while the counter-weight at the other end of the cord lifts it to a suitable height out of the way of the machine, as shown in the figure. The arms, *z*, at each end of the reel are then made straight, and secured in that position by their hooks. The winding of a fresh series of hanks once more begins, and the spiral plate, *k*, by the rod, *l*, again makes the carriage traverse gradually in a direction parallel to the axis of the reel.

The reel strikes a check after every 80 revolutions. These 80 revolutions form a ley or rap 120 yards long; and seven of them make up a hank, equal to 840 yards, or a little less than half a mile. The size of yarn is ascertained by weighing the hanks in a kind of balance, called a quadrant, and each size is put up separately in bundles of five or ten pounds weight. The cubical packages formed in the bundling-press, are wrapped neatly in paper, and thus sent into the market.

SECTION V.

The Singeing or Gassing of Yarn.

The fine cotton yarns which are used for making bobbin-net lace-thread, and for the hosiery trade, are generally subjected, first of all, to a singeing process by the flame of coal-gas, in a peculiar machine, to free them from their loose, divergent fibres, whereby they not only acquire a more level or compact appearance, but are raised to a higher number by the diminution of their weight per hank. In this way yarn of No. 90 will become No. 95.

The machine for this purpose may be said to consist of a series of gas jet-flames, through every one of which a thread is made to traverse several times, with a velocity corresponding to the quality of the yarn. The motion is given by the revolutions of winding and unwinding bobbins, turning from 2,500 to 3,500 times per minute. After singeing, the yarn is either reeled into hanks from the bobbins, or sent to the doubling-mill.

The winding process in the gassing machine will serve to illustrate the manner in which yarn is wound

from the smaller bobbins of a throstle-frame upon the larger bobbins of a warping-mill, with the addition of a contrivance for arresting the mechanism whenever a knot or foul point occurs in the thread. This modification is introduced in the gassing apparatus to prevent the flame from burning the thread when its rapid movement is thus stopped. The gas flame is, by this curious contrivance, suddenly turned aside, while the bobbin is at the same time lifted off the rotating barrel which turns it by friction, and is left at rest till the tenter female has had leisure to draw the knot through the slit, or to mend the defect. She now presses the bobbin down upon the carrier-barrel again, and restores the gas flame to its proper position under the running line of the yarn.

Fig. 81, presents an end view of an excellent

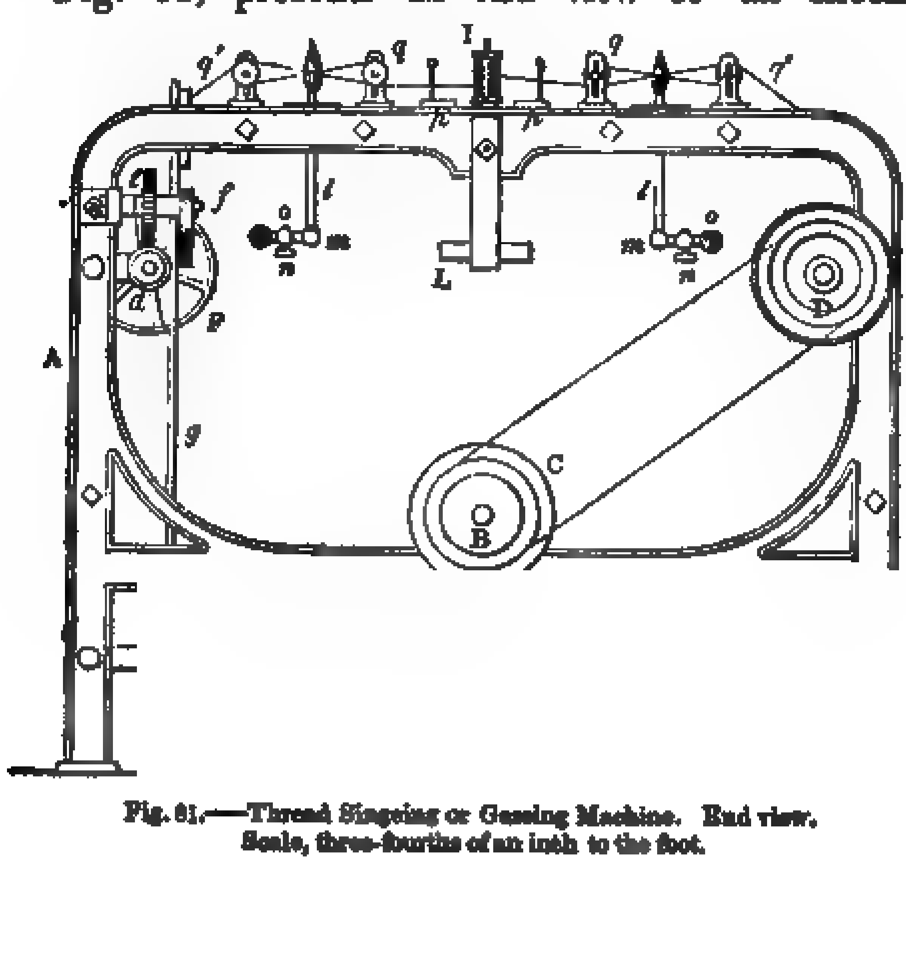


Fig. 81.—Thread Singeing or Gassing Machine. End view. Scale, three-fourths of an inch to the foot.

gassing machine, from which it will be seen to consist of two similar sides, or to be double.

Fig. 82 is a front view, showing a portion of the machine towards both ends; the middle, being a mere repetition of the parts here represented, has been left out.

Fig. 83 is a cross section of one-half of the machine, or of one of the two working sides, drawn to a double scale, in order to exhibit more clearly the mechanism for unwinding and winding one bobbin.

The gassing machine consists of two end frames, A, A, figs. 81 and 82, and if very long, it has a similar sustaining frame in the middle also. These frames are connected by four wooden rails stretching across the top, shown in section at *a* and *b*, fig. 83; and two other beams, *c*, lower down upon the sides of the

Fig. 82.—Thread Singeing or Gassing Machine. Front View.
Scale, three-fourths of an inch to the foot.

frame, fig. 82. B is a horizontal shaft driven from the mill-shafts under the ceiling of the apartment by the usual strap going over the outrigger fast and loose pulleys (not shown here). Upon each end of that shaft, B, is a threefold pulley, C, each connected by a strap with a similar pulley, D, fixed upon one of the horizontal shafts, E, E, which extends the whole length of the machine. Upon these shafts, on each side of the machine, sets of cylinders or pulleys, F, F, are made fast, which drive the winding-on bobbins laid upon them by the friction of contact with their surfaces. To these bobbins a different velocity may be imparted, according to the diameter of the pulley-groove in C and D, to which the cord or strap is applied.

G G are the bobbins; some of them resting upon their carrier-cylinders, F, in fig. 82, and some of them

Fig. 83.—Thread Singeing Machine. Cleaning and Tricker Mechanism.
Scale, one inch and a half to the foot.

suspended by being thrown out of geer, as when a knot arrests the motion of the thread.

Upon the end of the shafts, E, opposite to that where their driving-pulley, D, is fixed, is a worm-screw, *d*, fig. 82, which works into a wheel, *e*. With this wheel a heart-wheel, *f*, is connected, which revolves with the other upon the same stud, projecting from the frame. The heart-wheel presses against a roller attached to the lever, *g*, whose upper end is connected with the guide bar, *h*, figs. 82 and 83. A weight, *i*, appended to a band hanging over a little roller, *k*, fig. 82, serves to keep the bar, *h*, in contact with the heart-wheel, while the bar is shifted by the motion of the wheel, with the effect of guiding the thread from one end of the bobbins, G, G, to the other, during their rotation upon their carrier-cylinders, F, F.

The proper singeing mechanism is best seen in fig. 83. *a* and *b* are the stretcher-rails connecting the two end-frames of the machine, and forming a kind of a table; the space between them being filled with a piece of sheet-iron perforated with slits, for the passage of the gas tubes, *l*. These several upright tubes are connected by joints, *m*, with a small stop-cock, *n*, screwed into the two horizontal main gas-pipes, *o*, *o*, which extend through the whole length of the machine, and terminate in the larger gas-pipe of the factory. H is a small frame, in which are fixed top and under step-bearings of a line of spindles, equal in number to that of the winding-on bobbins of both sides of the machine. Upon these spindles the bobbins, I, are set. From these the yarn is wound off. *p* is a bar furnished with glass pegs or pins, for the

purpose of guiding the threads from one-half the number of spindles to each side of the machine. *q* and *q'* are two small rollers, over which the yarn is guided to and fro in its passage through the flame of the gas jets from *l*; and they may be fixed higher or lower in their respective slot bearings, so as to place the yarn in the most suitable part of the flame.

The yarn unwound from the bobbin, I, is guided round the glass pin of the bar, *p*, it passes through a narrow slit, or cleaner in the lever, *z*, (to be presently described,) under the one roller, *q*, over the other roller, *q'*, down to the guide aperture, *r*, of the guide bar. A glass rod which is fixed to the edge of this bar, prevents its friction upon the wood.

The yarn which passes through the aperture, *r*, is thereby guided in the proper direction for distributing itself equably over the winding-on bobbins. These bobbins revolve upon a stud projecting from the end of a single armed lever, *s*, which moves freely upon the fulcrum, *t*. When the end, *v*, of the lever, *u*, *u*, is depressed, the bobbins, G, come to bear upon the rotating carrier-pulleys, F. But when the end, *v*, is raised, it lifts the bobbins, as if by a hand, out of contact with the said driving-cylinders. The long lever, *u*, *u*, moves about the same fulcrum, *t*, with the bobbin lever-arm, *s*, being bent in such a way that when its handle, *v*, is lifted, it catches under, *s*, and lifts it also. In a slot of the lever, *u*, one arm of the bell-crank lever, *w*, plays. This bent lever has its fulcrum at *x*, its other arm is upright, and embraces with its fork end, *y*, the gas-tube, *l*. *z z* is an upright very light lever, having at its upper end a fine slit, through which the thread passes, and at its under end

a notch, *a'*, for laying hold (upon occasion) of the stud-point, *b'*. This stud projects from the bent lever, *u*, near to its end.

L is a board or bench, extending the whole length of the machine; and upon it the stud-end of the lever, *u*, rests, unless when the stud *b*, is laid hold of and lifted by the notch, *a'*, of the lever, *z*, *z*.

d' is a tube of sheet-iron, serving as a chimney over the gas flame, to prevent its flickering by cross draughts of air.

Suppose now the yarn of the bobbins, I, to be attached to the barrels of the bobbins, G, as shown in fig. 83. The attendant female depresses with her finger the handle, *v*, of the lever, *u*, and thereby raises its other and heavier end till its stud, *b'*, entering into the notch, *a'*, keeps it suspended in that position; whereby the bobbin, G, is allowed to press upon the rotating pulley, F, by its own weight and that of its lever, *s*. The bobbin immediately begins to revolve, and to wind on yarn, whilst the bell-crank, *w*, moved by the oblong slot of the lever, *u*, sets the gas-tube in the position proper for applying the flame to the thread in its passage between the rollers, *q* and *q'*, figs. 81, and 83. Should a knot or rough point of the thread present itself, too large to pass through the cleaner-slit in the top of the lever, *z*, it will give by its swift motion a twitch to the lever, and turn it so as to release or unlock the notch in its under arm, from the stud, *b*, of the lever, *u*, *u*, and thus let the heavy end of this lever fall down upon the bench, L. By this movement the under short arm of the bell-crank, *w*, gets also a twitch from the slot in *u*, and this in its turn shifts the gas-tube, *l*, aside by the simultaneous

motion of the forked end, *y* of *w*. Meanwhile the arm, *v*, of lever, *u*, being raised, lifts the lever, *s*, along with the bobbin, G, supported by the horizontal studs at its end. By these combined actions (all proceeding from the trigger jerk given to *x*, by the knot in the thread) the whole mechanism for singeing and winding that thread is thrown out of geer, or rendered inoperative.

The tenter, who is paid according to the quantity and goodness of her work, in casting her eye over the machine, sees at a glance the bobbins which are reposing above the line of their star-pulleys, F′, and having corrected the defects in the threads, sets them immediately in train with the machinery, merely by depressing the handle, *v*, which once more puts the trigger apparatus at the other end of the lever, *u*, in geer with the general driving-shaft, as above described.

SECTION VI.

Doubling and Twisting of Yarn; or the Thread Manufacture.

Cotton yarns are formed into different kinds of thread, according to the purpose which it is to serve. Thus we have, bobbin-net, lace-thread, stocking-thread, sewing-thread, &c. Two or more single yarns laid parallel and twisted together, constitute thread. Lace-thread is made always from the finest numbers of yarn, from No. 140 to No. 350. It consists of two threads twisted together by means of an appropriate machine, presently to be described. The manufacture of sewing-thread differs in nothing from the preceding, except that usually three or more single yarns are

here twisted together into one. Stocking-thread is made of more or fewer yarns, according to the object of the manufacturer. All good thread should be gassed before it is taken to the doubling and twisting-mill.

This operation is improved by passing the yarns, immediately before being doubled and twisted, through a trough containing a weak solution of starch, which promotes the compactness, strength and smoothness of the thread. The twist is usually given to the doubled yarns in an opposite direction to the twist of the individual yarns in the spinning machines. It is effected by spindles and flys, like those of the common throstle. The doubling-machine is provided with one pair of rollers, similar to the drawing-rollers of the throstle, but larger in dimension, for the purpose of delivering the yarns at a measured rate to the twisting-spindles, to ensure sufficient tension and time for equable and proper torsion.

The thread is wound upon bobbins, revolving round spindles, upon the friction principle of the throstle-frame.

The bobbins rub by their under disc-end upon the copping-rail, and receive from it, by means of a heart-wheel, the usual traverse motion, up and down, for the equable distribution of the thread over their barrels.

The machine represented in the figs. 84, 85, and 86, is constructed for doubling fine yarn into lace-thread from the mule-spindle cops.

To adapt it for doubling the yarn from throstle-bobbins, nothing is necessary but to erect a frame for carrying the spindles upon which these bobbins would be set, in the place of the creel and skewers of the present machine.

Fig. 84 is the view of that end of the machine to which the motion is communicated from the mill-shaft.

Fig. 85 is one of the front views, which are similar on both faces, the machine being double, like the throstle-frame.

Fig. 86 exhibits a part of a transverse section, being an analysis of the apparatus subservient to one spindle. It is drawn upon double the scale of the other two figures.

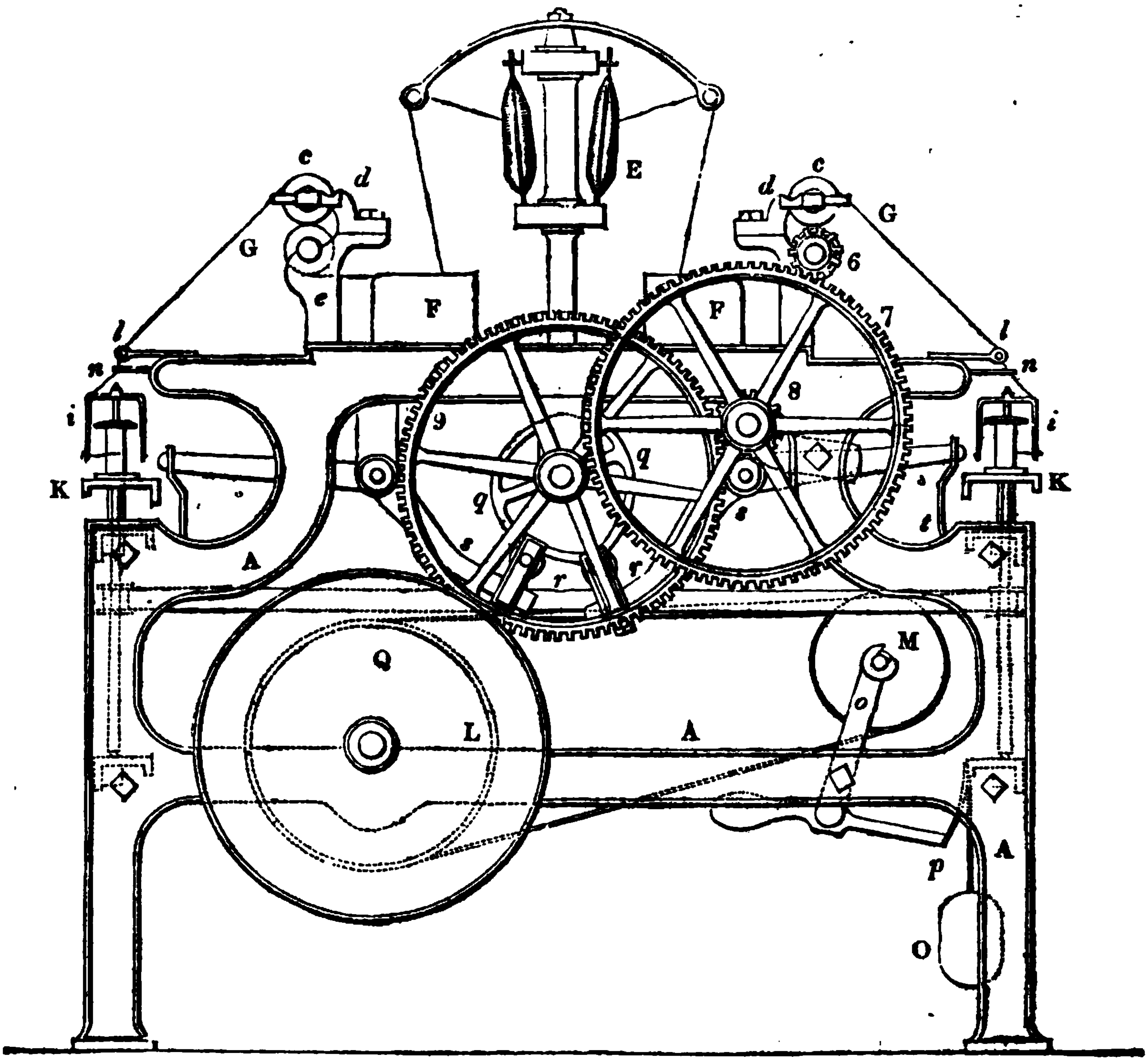


Fig. 84.—Doubling and Twisting Frame. End view. Scale, one inch to the foot.

A A are the two cast-iron end frames, connected at their tops by two beams, B, B; and upon each side by two other beams, C and D, for the purpose of carrying the bearings of the spindles.

E is the creel upon which the cops are set up in two parallel rows, one upon each side or face of the machine, the number of which cops (or bobbins) must be double, triple, &c., the number of the twisting spindles, *i*, *i*.

F F are two troughs filled with water, or very thin starch paste, through which the yarns are made to pass under a glass rod, *a*, in which are concentric grooves, to keep the yarns in one line of traction. G G are two sets of rollers, consisting of smooth iron under rollers, *b*, and light wooden top rollers, *c*; each set revolving by its iron axis in slot bearings, *d*, which are screwed upon the bearings, *e*, of the under roller. The upper rollers traverse, and consist of as many different ones as there are threads; each of them being held upon the under roller by tops sliding in vertical slots.

This pair of rollers serves, as we have said, to draw the yarn from the cops (or throstle bobbins) through the trough F, and over its rounded edge, *f*, which is covered with flannel for the purpose of wiping the superfluous moisture from the yarn, and delivering it in two parallel lines to the spindles, which twist them together as they proceed from the roller, G.

Figure 85 shows the thread first passing beneath the under-roller, *b*, then round about it, and over the roller, *c*, down to the fly of the spindle, *i*, *i*.

H H are the spindle-stems, having their upper brasses or collars, *g*, fixed in the beam, C, and their under step-bushes, *h*, in the beam D. *i i* are the flies,

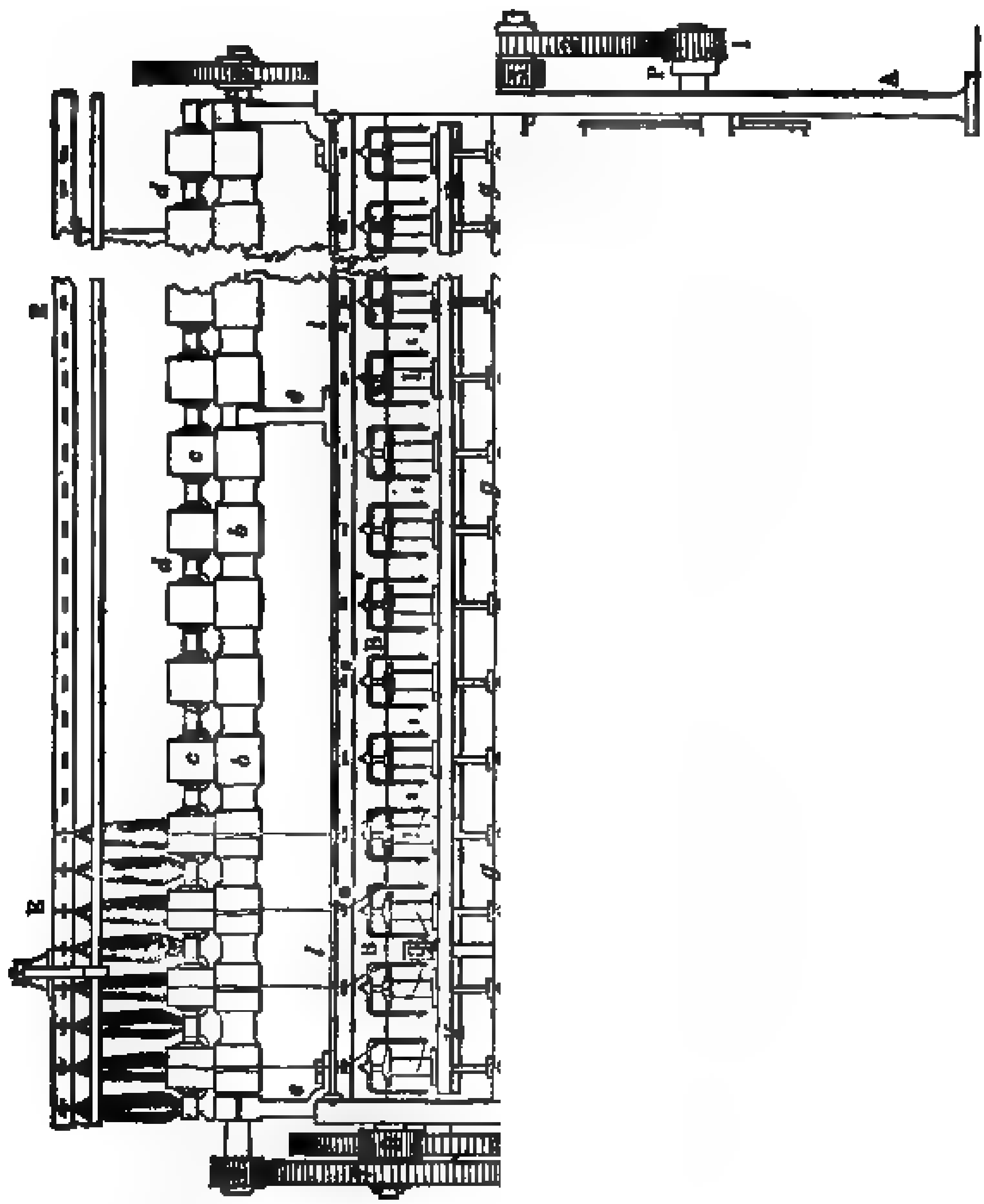


Fig. [illegible].—Doubling and Twisting Frame. Front view. Scale, one inch to the foot.

and *k* the wharves or pulleys upon the spindles, for making these revolve by straps. I I are the bobbins, which rest upon the copping-rail, K, K, and are moved up and down with it. *l* is a smooth wire, for the yarn to glide over. It is fixed to a rail or board, *m*, extending the whole length of the machine. *n n* are wire eyelets, through which the yarn passes in its way to get twisted underneath by the spindles.

L, fig. 84, is a large tin drum, which imparts motion to the spindles by bands or straps; one band passing round the wharves of four spindles, two upon each side of the machine. These bands are kept in proper tension by the tightening pulleys, M, M. These pulleys rest with their axes upon the extremities of the arms *o*, of bell-crank levers, whose other extremities (figs. 84 and 85 at bottom) suspend weights, O, attached to a curved plate, *p*, fixed to their points. The straps of the tin-plate drum, or cylinder, L, go first round the wharves of two spindles upon the right-hand side, thence round two upon the left-hand side, and thereafter over the tightening pulley, M, to the drum, L, as plainly shown by dotted lines in fig. 84.

The train of motions in this machine may be easily traced upon the shaft, P, of the tin-plate drum, L. Exterior to the frame-work at the end, are the usual outrigger fast and loose pulleys, Q, for driving the machine. The other end of the shaft, P, (fig. 85), bears the pinion, 1, which drives the wheel, 2, and thereby a pinion, 3, turning loose with the latter upon a stud. The pinion, 3, drives a carrier-wheel, 4, whence the motion is given to the wheel, 5, upon the iron roller-shaft. The wheel, 4, by another similar carrier-wheel, drives a similar wheel upon the iron

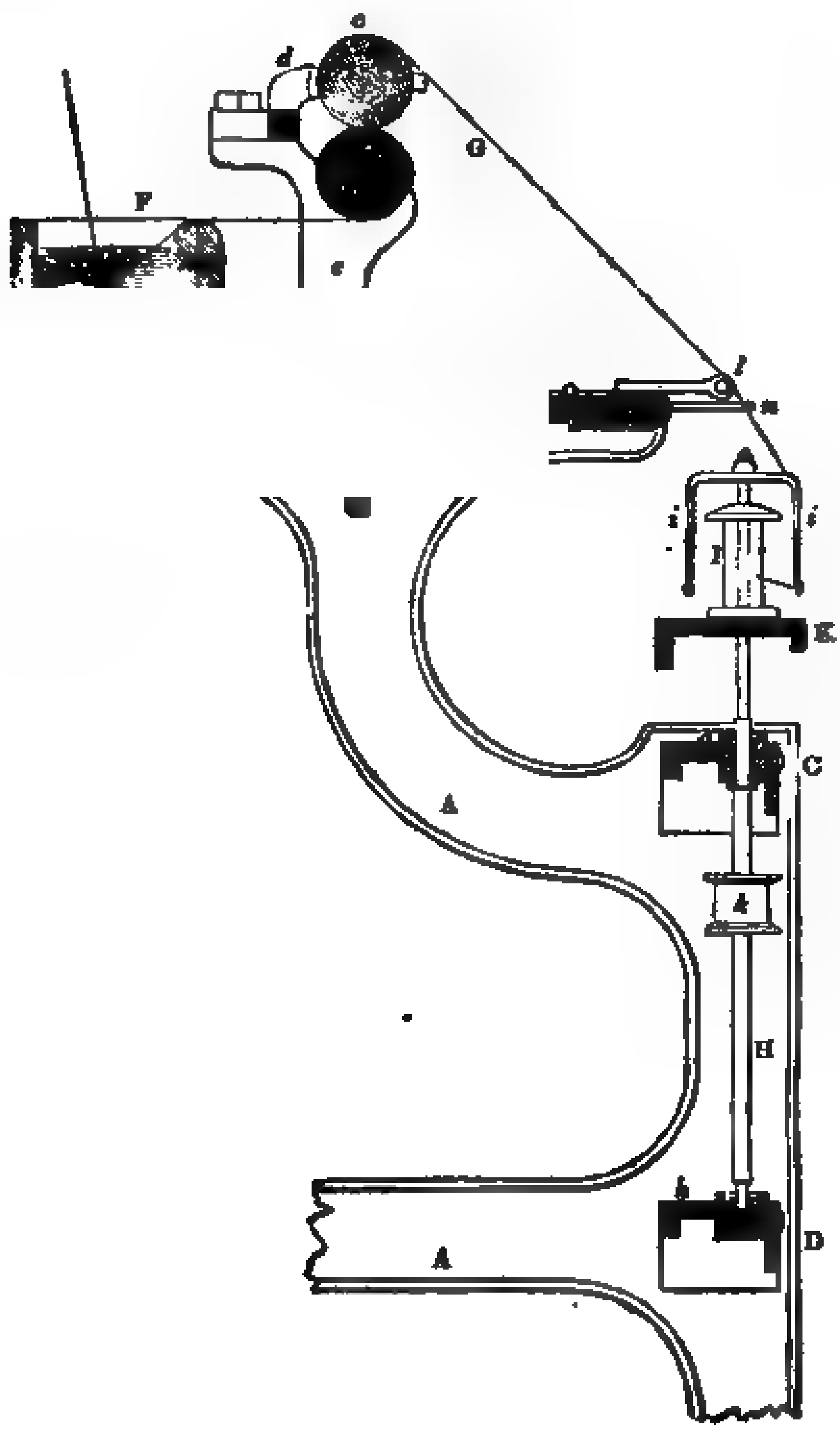


Fig. 96.—Doubling and Twisting Frame. Details of Spindle Mechanism. Scale, two inches to the foot.

roller-shaft of the other side (the latter cannot be seen in the view, fig. 85.)

Upon the end of the machine represented in fig. 84, a pinion, 6, is attached to the one roller, which drives the wheel, 7, and by a pinion, 8, on the same axis, also the wheel, 9, fixed upon the horizontal shaft that extends the whole length of the machine, for carrying several equal heart-wheels, such as *q*, *q*. Each of these wheels acts upon two rollers, *r*, *r*, attached to the ends of the one set of arms of the curved levers, *s*, *s*. The other arms of these levers are connected with the copping-rails, K, K, by the links, *t*, *t*, on each side of the machine, fixed to the rods *u*, which are screwed into the said copping-rail, and slide in the beams, C and D, fig. 85. In this way the copping-rail is made to rise and fall alternately, as the revolving heart-wheels, *q*, *q*, depress or elevate the arms of the levers *s*, *s*.

In the thread machine there are three distinct simultaneous movements; 1. That of the rollers, or, more properly speaking, the under rollers, for the upper are carried round merely by the friction of the former; 2. That of the spindles; and 3. The traverse or up-and-down motion of the bobbins.

The twist of the thread ought to be proportional to its fineness; with which view the machine is so constructed as to permit of its wheels and pinions being exchanged for others with different numbers of teeth.

It is obvious that the motion communicated to the under rollers from the main shaft, P, is retarded; while that communicated to the spindles is accelerated. Thus, for one turn of the shaft, P, or the pinion, 1, upon its remote end, the wheel, 2, will make $\frac{1}{5{\cdot}5}$ of a turn; and for one of the pinion, 3, upon the axis of 2,

the wheel, 4, will make $\frac{1}{4}$ of a turn; hence the wheel, 5, of the same size as the carrier-wheel, 4, makes one turn for 16·5 turns of the steam-shaft, P. The surface of the under rollers turned at this rate by wheel, 5, is $75\frac{43}{100}$ twelfths of an inch, being 24 twelfths, or 2 inches in diameter; and therefore these rollers will deliver $\frac{7543}{165} = 4{\cdot}57$ twelfths of an inch of thread for each revolution of P.

The drum, L, L, having ten times the diameter of the wharves of the spindles, each turn of it will give ten revolutions to the spindles. Hence while 4·57 twelfths of an inch are delivered, the spindles turn ten times round, or give ten twists to that portion, being fully 26 twists per inch.

Whatever be the number of the yarn, the traverse motion of the bobbins remains unchanged.

SECTION VII.

The Bundle-Press.

The object of this machine is to pack up the hanks in bundles of a few pounds weight each, and to compress them into such a moderate compass as may allow them to be transported to a distant market with little cost or risk of injury. Though small in size, the bundle-press is characterized by the same ingenuity and mechanical soundness of construction which distinguish the Manchester workmanship in general.

Fig. 87 shows the front view, or the face opposite to the station of the packer. Fig. 88 is an end view.

A A is the strong frame of cast iron.

B B is a wooden table fixed to the frame. Its

Fig. 88.

Fig. 87.

Yarn Bundle or Packing Press. Scale, three-fourths of an inch to the foot.
Fig. 87. Front view. Fig. 88. End view.

right-hand end serves for holding a quantity of yarn ready to the packer's hand. Upon the left-hand side of the table are laid the papers and twine used in making up the bundles.

C, is a wheel which is moved by the pinion, D. The pinion is fixed upon a shaft which is turned round by the arms of the cross, F. Upon the same shaft is a ratchet-wheel, E, furnished with the usual click, *a*, to arrest the shaft at the point last arrived at, by its revolution in the direction of the arrows.

Upon one of the radial arms of the wheel, C, is cast a boss, on which the two connecting rods, G, G, are fixed. The upper ends of these rods are joined by the press plate, H, which must, therefore, move upwards when the wheel, C, is turned round. In order to make the plate, H, ascend in a vertical direction, it carries two guide-bars, I, I, which move between flanges cast upon the inside of the frames, A, A.

The part of the machine by which the pressing is performed, consists of two sets of flat bars or rulers, *b*, *b*, &c., between which the press-plate moves up and down. Each set consists of five bars, which are screwed against the top of the frame A, but leave sufficient space between them for receiving the binding packthread or twine.

The top of the press consists of five rails, *c*, *c*, *c*, *c*, *c*, which fit the five bars of the sides. They are connected with one of these sets by joints, *d*, *d*, *d*, and are raised up to let in the yarn, and to take out the bundle. The other ends of these rails *c*, *c*, *c*, are laid upon the five front bars, and are secured in their places by rods, *e*, *e*, *e*, which turn round the joints, *f*, *f*, *f*, and are let into slits of the rails, *e*, *e*, *e*, the projecting heads, *g*, *g*, *g*

of these rods preventing the rails from rising. When the pressing has been performed, the rods are pushed from the slits into the inclined position, *g*, *e*, *f*, seen in fig. 87, which they retain by means of the little tails at their bottom, which bear against the bars, *b*, *b*. The packer then raises the top rails into the oblique position represented in the same figure at *c′*.

The iron press-plate is covered with a smooth piece of hard wood, in which are cut grooves for laying the packthread or twine in correspondence with the spaces between the side bars, *b*, *b*. He lays these threads in their places, when the press-plate is at its lowest level; he then fills the space between the bars *b b* with hanks previously twisted slightly, and neatly folded together, and lowering the top rails *c*, *c*, *c*, pushes the key-rods *e*, *e*, *e* into the slits of the rails, and begins to turn the cross F so as to drive the wheel C by the pinion D, and move the plate H upwards. After having given sufficient compression to the bundle, he binds the threads together round it, after which he pushes the click out of the ratchet-tooth, when the elastic rebound of the cotton drives down the press plate to its lowest level. He now takes out the bundle, and repeats the same operations.

From the increasing magnitude of the angle formed by the acting spoke of the wheel, and the pushing rods G, G, the mechanical advantage becomes exceedingly great towards the conclusion of the pressure, and thus enables a feeble arm to form a very compact bundle.

CHAPTER V.

WEAVING.

SECTION I.—Warping-Mill.

Fig. 80.—Ancient Warping Frames, from Montfaucon.

The preparatory step to weaving is arranging the warp-yarn in truly parallel layers upon a wooden beam. This operation is effected by the aid of an ingenious machine, called the warping-mill.

The warp-yarn, as spun either in the throstle or the

mule, must be wound from the small bobbins or cops, upon bobbins of a much larger size, suited to the adjustments of the warping-mill. This transfer is made by a winding-frame, very similar to that described for gassing yarn, but greatly more simple, from the absence of the singeing apparatus. In the present case, the large bobbins are laid horizontally upon rotating-pulleys, and revolve by surface friction, so as to wind-on the yarn from the smaller bobbins or cops set upright or horizontally upon skewers in an adjoining frame or creel. The threads are made to pass through glass hooks fixed upon a guide-bar, which traverses to the right and left, through a space equal to the barrel of the large bobbin, so as to distribute the yarn evenly over its surface. (See this apparatus described under the gassing machine.)

From these bobbins the yarn is next transferred to another machine called the warping-mill. Here the yarn intended to form the warp of one long web or *cut* in the power-loom is generally wound in eight portions upon eight separate rollers; from which it is united upon one roller or warp-beam in the power-loom dressing machine. By the above plan, the attendant on the warping-mill has only to watch one-eighth part of the whole yarns, from two to four thousand in number, which may go to form the entire breadth of the web; and she can, therefore, more readily recognize the particular thread which breaks, and mend it immediately, so as to preserve all the yarns of the same length.

A warping-mill of the latest and most approved construction, is represented in plate VII., figs. 1 and 2. Fig. 1 shows an end view of the machine; and fig. 2 a view seen from above, or a ground-plan. In

both figures the bobbin-frame is shown only in part; the rest, being a repetition, may be supposed extended to suit any number of threads or breadth of web.

B B is the iron frame-work of the machine, upon which the three wooden rollers C, C′, and C″, rest, which guide the yarns given off by the bobbins, after they pass between the brass wires, *a*, fixed upon the wooden bar, *b*. To prevent the threads of the bobbins nearest the frame, B, from rubbing upon the bar, *b*, its edge is rounded off with a smooth wire, *c*. D, are six prismatic bars placed horizontally upon the top of the frames B, and extending right across the machine.

E are plates cast on the frame-work, having upon their inner surfaces six upright ribs corresponding with the bars, D; the breadths of the latter being equal to the intervals or square channels between the said ribs. *d* is another guide for conducting the yarn, consisting also of upright wires, like a comb, between which the threads pass.

F is a small roller to support the weight of the yarn, and to prevent its rubbing upon the bars, D and *d*, in its rapid motion to the winding-beam, or yarn-roller, G, shown by dotted lines in plan (fig. 2). Upon its ends, at a distance asunder suited to the breadth of the yarn-roll, are two light cast-iron plates, *e*, *e*, which are furnished with a projection that fits into a longitudinal groove in the wooden roller, and may be thus shifted farther in upon the roller, according to the breadth of the spread yarn. The tooth or feather of the end plate, by entering the groove cut in the roller, is prevented from slipping round upon it.

The warp-beam, G, lies with its iron axis in two slots of the brackets, *f*, *f*, made fast to the cross-frame piece of the frame, B, and presses upon the roller, H, with its

whole weight. This roller is made of wooden spars, screwed upon the circumference of several iron rings wedged upon a shaft, so as to form a hollow cylinder. The wood is then covered with flannel, upon which the warp-roller is laid.

This roller, H, lies with its axis in bearings attached to the frame B, and carries at the one end the usual fast and loose pulleys I, by which it receives motion through a strap, from a pulley on the mill-shaft, and imparts that motion to the roller G by surface friction.

Upon the shaft of the roller H there are two wheels, K, K, which enable the attendant to turn backwards the roller H, and thence also the yarn-roller G, in case a thread should break and its end should run on. It is necessary, however, first of all, to detach the warping-mill from the driving-shaft of the factory, by shifting the strap upon the outrigger loose pulley at I. To facilitate the throwing the machine out of geer in a moment, there is a fork, *g*, at the bent end of a bar, which extends across the frame, and presents a handle at *h*, for shifting the strap and arresting the movement.

The working of this machine will hardly need any minute elucidation. The yarns proceeding from the bobbins at A go over the roller C, under the roller C′, and over the roller C″, thereby bringing the threads of all the bobbins into one horizontal plane. They pass thence over the bars D, through between the guide wires *d*, *d*, wind over the roller G′, as it revolves by friction of contact with the rotatory roller H, its axis being at liberty to rise in the slots of *f*, *f*, in proportion as the diameter of the barrel increases. For the pur-

pose of showing the threads more plainly, the whole of the machine is painted black, so that the warper sees at once if there be a deficient white thread upon the dark ground. She immediately stops the mechanism, takes up one of the six smooth prismatic rods out of the grooves in the brackets *i*, *i*, and lays it down across the yarn in the interval between the two farthest bars D, so that the ends of the rods lie between the ribs of the side plate E. She then turns the roller G back, by acting with her hand upon one of the wheels K, K, and thereby causes the yarn to wind off, the slack of which immediately falls down in doubled threads under the weight of the iron rod between two contiguous ribs of the side plate E, like a window casement sliding down in its side grooves.

If still she cannot recover or reach the broken end of the thread, she places another of the smooth rods in the next partition of the bars D; which, descending in the cell, carries before it another double length of the yarns, as they are uncoiled, by the retrograde motion given to the roller G. The warper goes on to recal the wound-up yarns in this manner, without any possibility of ravelling them, or affecting their parallelism, till she finds and repairs the broken ends. The roller G must now be turned slowly forwards till all the prismatic rods be lifted from the ground, and disengaged from the travelling warp, when they are restored to their grooves in the brackets *i*, *i*. The strap is next shifted upon the fast pulley at I, and all moves smoothly once more, till another thread chances to break. As the bringing back of the broken ends is an irksome process, which loses time, and impairs her wages, it is a lesson which inculcates vigilance in no mmon degree.

The warp is now ready to be transferred to the dressing machine.

SECTION II.

The Dressing Machine.

Consists of the following principal parts, 1. The frames for carrying the rollers which have been filled with yarn upon the warping machine. Generally eight rollers are used to compose a warp, and they are arranged in two sets at the opposite ends of the machine.

2. The sizing apparatus in which the warp-yarn of four of the said rollers passes between two cylinders, one of which is immersed in a trough with size. Whilst, therefore, the lower cylinder gives size to the yarn, the upper one squeezes out the superfluous quantity of the paste.

3. The part of the machine where the paste is rubbed into the fibres of the yarn, and smoothed over by means of brushes. In this part the machines differ from each other, according to the kind of brushes that are used. In some dressing machines, two cylinders covered with brushes, one over, and one under the warp, revolve in a contrary direction to that of the yarns. In another sort of dressing machines, two flat brushes, one over and one under the warp, are moved to and fro in such a way that they touch the yarn only in one direction of their movement. It is obvious that, in the latter kind of machines, the yarn can be damaged only upon the first entering of the brushes (which, however, is performed very gradually), whilst in the cylindrical, the revolving bristles are constantly apt to rub and tear the delicate threads.

4. The drying of the size in the warp is performed by passing it over a box or chest filled with steam. In addition to the steam-chest, a fan is used for changing the air, and thus promoting a quick evaporation.

5. The last operation which is done in this machine is the winding of the warp upon the main yarn-beam, which is to be put into the loom. The two parts of the warp which have till that time been worked separately on either end of the machine are united here, and carried through a reed to produce a regular winding upon the yarn-beam. The revolving of the latter is the cause of the warp's travelling from the eight yarn-beams through the five operations just mentioned.

The dressing-machine is shown in a longitudinal view in figs. 1, 2, 3, and 4, plate VIII. The drawing contains one end of the machine, in which one half of the warp is prepared, and the middle part of it, where both parts of the warp are united and wound up together. The other end of the machine is exactly the same as that represented, and therefore is left out to reduce the size of the engraving. Figs. 1, 2, 3, and 4 represent all the essential parts of the machine which will be mentioned in the following description.

A, A is one of the frames which carry the yarn rollers B, B, B, B, as prepared at the warping mill. The rollers can be fixed at successive heights in order to make the yarn from the rearmost rollers clear the front ones.

The yarn of all the four rollers (which contain different numbers of threads according to the various breadths and fineness of the cloth to be woven,) is carried through a warp reed, *a*. This reed is formed,

as in general, (see fig. 2,) of brass wires, but much stronger, and with wider intervals than those commonly used in weaving. Behind the reed *a* is a small roller, *b*, which revolves by the friction of the travelling warp, and serves to collect the yarn of all the beams in one horizontal plane.

C is a large wooden cylinder immersed in a wooden trough, D, which is filled with glue, paste, or starch. This cylinder is pressed by another smaller one, E, of iron, which is covered with cloth; by drawing the warp forward, and thereby turning the cylinders C and E, the latter squeeze out the superfluous part of the size which had previously been raised from the trough by the surface of the former roller. As the weight of the cylinder C is very considerable, and would therefore produce too much friction to be safely turned by the travelling warp, its shaft, instead of lying in bearings, turns upon friction-rollers, *c, c*. From the sizing cylinder C the warp travels in the direction marked *d, d, d*, thus passing through the reeds *e, e, e*, under the lathe roller F, through what are called the heddles G, and through the large reed H to the yarn-beam I. The other half of the warp on the other end of the machine, comes in the direction *d′, d′, d′*, passes under the roller F′, through the same heddles *g*, and reed H, to the said yarn-beam I, which is similar to those used on the warping machine. To prevent the threads from sticking together, and to make it easier for the dresser to mend any broken ones, the warp is separated by the wooden rods *f, f, f*, (called lease-rods.)

K is a box constructed either of deals or sheet iron, and screwed to the frame L of the central part of the machine. In this box, and upon two slender beams,

Z, which connect the frames L and A, are sheet-iron cases, M and M′, (see the dotted lines in the figure,) which are supplied with steam from a main pipe, which serves, at the same time, to heat the room.

N is the main shaft which goes across the machine; on the end of which are three pulleys, a fixed and a loose one, O, to give motion to the machine from the shafts, and a third pulley, P, to drive the fan Q.

The said shaft N has two cranks in the centre of the machine, which stand at right angles to one another, the use of which will be explained hereafter. On the shaft N there is also a conical pulley R, which corresponds with a similar one, S, set in the reverse direction of the former. Hence, by moving a strap from the small diameter of the pulley R to its larger diameter, and at the same time, from the larger diameter to the smaller of the pulley S, the velocity of the cone S will be gradually increased, and by moving the strap in the contrary way it will be decreased, whilst the shaft N continues to revolve with equal velocity. The movement of the said strap is effected by turning a handle, *g*, on the other side of the machine, and shifting, by means of a screw, the guide *h*, which keeps the strap at the place deemed proper by the dresser. On the short shaft where the cone S is fixed, there is also a small pinion (not seen in this view of the machine), which works in the wheel *i*. Fixed to *i* is a bevel-wheel, *k*, which drives another such wheel, *l*, fixed upon a shaft sloping upwards, *m*, seen only in dotted lines, as those parts last mentioned are attached to the other side of the machine. This shaft *m*, by means of two bevel-wheels, *n* and *o*, drives the yarn-beam I, as is represented in fig. 4. The wheel *o* moves

between two bearings, with its shaft *p*, which can be shifted through the boss of the wheel, according to the length of the yarn-beam which is to be put into the machine. When the yarn-beam which lies with its other end in the bearing *q* has been put in a hole made for that purpose in the shaft *p*, fig. 4, the wheel *o* is screwed fast upon the shaft, and is now able to turn the beam by means of *r* and *s*.

By the revolving of the yarn-beam I, as just described, the warp is drawn from the rollers B, B, B, B, in the directions *d, d, d,* and *d′, d′, d′*, and wound upon its surface so as to increase its diameter, and, of course, the velocity with which the yarn is drawn in through the operation, and thereby it would prevent its getting dried before it is wound on the beam. The cones R and S are contrived so as to obviate this inconvenience. From them the motion is given to the wheels and shafts already described, and to the yarn-beam I. As soon as the dresser observes that the warp is not perfectly dried, he decreases the velocity of the machinery by turning the handle *g*, and moving the strap which turns the cone S towards the smaller diameter of the cone R. If he finds that he could work the machine a little quicker, he turns the handle the other way.

Q is a fan of three wings, working between the two halves of the warp which come up from the two ends of the machine.

By drawing the hot air from underneath the steam-boxes M, M′, and blowing it against the expanded warp, it serves very powerfully to dry it. This is an arrangement which has been lately adopted.

The fan Q is put in motion by a strap which comes from the pulley *t* to the pulley seen under the letter *u*.

With the first one is connected another pulley v (seen in the figure only in dotted lines), which is put in motion by a strap from the large pulley P, P, on the shaft N. On the shaft of one of the rollers F′, which are made of single lathes to prevent the sized yarn from sticking to them, is a worm working in the wheel w, which strikes, after each revolution, against a bell, in order to indicate the quantity of warp wound upon the beam I. This point is marked by the dresser with a line of coloured paste.

In order to wind on the yarn evenly between the two side plates of the yarn-beam, the reed-frame (that is, the frame into which a very broad reed, made with long wire, is put), and through which the yarn passes just before it is wound upon the yarn-beam, can be moved a little to the right or left by means of a handle, y, which moves a screw working in a nut attached to the said frame. This lies upon two pieces of wood screwed against the frame, L, of the machine. The heddle-frame g, which also lies loose upon two such pieces of wood, is adjusted to the former, in order to give as little friction to the yarn as possible. *See* fig. 4.

It remains now for us to give a description of the brushing apparatus, which has not hitherto been mentioned, because it is an addition not absolutely necessary, but a good assistance in producing a well-dressed warp. In the machine here represented, the rectilinear system of brushing has been adopted.

A′ and B′ are brushes like that represented in fig. 3, the one working on the top, the other from beneath, against the warp; both are fixed with the ends upon iron bars, C′, which work in joints, a' and b', upon the levers E′ and D′. The lever D′ moves round a bear-

ing, c', fixed to the floor. The other lever E′, however, has its bearing on the end of an arm, H′, which is fixed to the end of a shaft, e'. Upon the centre of the shaft is fitted another lever, G′, the end of which is connected by a long rod, I′, with the first crank in the shaft N mentioned before. The other crank of this shaft, which moves ninety degrees from the former, is connected by a similar rod, H′, with a bearing attached to pieces connecting the levers E′ of the two sides of the machine.

f' is a counter-weight working upon the shaft e' to balance the weight of the brushes. It will now be perceived that by moving the crank-shaft N from the position the drawing shows it in, the first crank will move the lever G′, depress E′, and of course also gradually depress the brush A′ upon the warp, whilst the other one B′ is gradually lifted up against it (the bar C′ turning upon the joint b').

At the same time, however, the second crank is drawing the frame E′ and also the bar C′ forward, in the same way as a weaver used to apply the dressing by hand upon the warp in the loom. When the cranks have moved through 180 degrees, the brushes will have left the warp, and will move backwards at som distance above and beneath the warp, without touching it.

SECTION III.

The Sizing Machine.

Instead of the dressing machine, in which a small quantity of paste is applied to the surface of the yarn, and is rubbed in between the fibres by means of brushes,

there is now sometimes used a very simple apparatus to impregnate the yarn with size.

It is a fact well known, particularly to dyers, that stuffs are not well penetrated by a fluid, &c., if they are not alternately immersed in the fluid, and then squeezed out again, for the purpose of expelling the air contained in the fibrous matter. With this view, the sizing machine has been constructed, which consists of a large trough filled with size through which

Fig. [illegible]

Lillie's Sizing Machine.—Scale, half an inch to the foot.

the warp is drawn, but, instead of passing it simply through the fluid, it passes over a set of rollers which turn by the friction of the travelling warp. This motion, by which the warp is pressed tight upon the rollers, and left loose again in the space between every two of them, effects a complete impregnation of the fibres of the yarn.

The sizing machine is represented in the annexed figures. Fig. 90 is a longitudinal section, in which there are represented only nine of the rollers, instead of twenty and more as are generally used.

Fig. 91 shows a cross section of the same machine by which it will be perceived that two different warps are managed in the machine at the same time.

A, A, is a trough of cast-iron plates screwed together, having the joints secured with cement. To the bottom plate is cast, in the direction of its length, a channel, B, which serves as a steam case, and which communicates with the inner trough by the openings *a, a, a.* These openings are covered with small valves, which are lifted by the steam coming from the pipe C in the channel B, which, however, prevent the fluid contained in the trough from entering the steam pipe, if this should be empty of steam. D, D are very light cast-iron pulleys or rollers, which revolve upon rods, screwed across the trough. They are arranged in two rows one over another, to make the warp travel up and down. Between these two sets of rollers, and through the length of the trough, are fixed two rods E, E, for either of the warps, as will be seen in the section, fig. 91. They are about four inches apart, and serve to keep the warp in the centre of the rollers D, D, whilst it is travelling from one end of the machine to the

other, and remaining constantly immersed in the fluid which fills the trough to about two inches under the upper edge.

After having passed all the rollers D, D, as is seen in fig. 90, the warp is squeezed between two large wooden rollers F, F, which are pressed together by weights suspended at the levers G.

The superfluous moisture is here expelled, and runs back into the trough, whilst the warp is led either over the cylinders of a drying machine, like those used for the drying of dyed or printed goods, or it is wound up in a bundle, and carried into a hot room. The better plan would be to let it pass over the rollers of a hot flue, winding the end of the warp direct upon the yarn-roller, after the threads have been first drawn through a reed.

An eminent manufacturer at Hyde makes the paste for dressing his warps in the following way.

Of Calcutta flour, at 14*s*. per cwt., 140 pounds are put into each paste-tub, whose average depth is 20 inches, and width 30 inches. The tub is filled up to nearly the brim with cold water, and the materials being well mixed, are left alone for three days. The glutinous matter which collects at top is skimmed off; the mixture is now run down into a cylindric vessel of cast iron, in which vanes are made to revolve by a vertical spindle, so as to triturate the whole well together, while steam is admitted from a pipe which dips down near to the bottom. The paste being boiled in this way for an hour, is then run off into casks, in which it is left during three weeks; at the end of this time, it is smoothed or levigated by being forced hrough between two rollers revolving almost in con-

tact with each other, at the bottom of a pyramidal hopper, into whose wide mouth the paste is ladled.

Mr. Lillie's sizing machines will dress a length of warp of upwards of one mile in the course of an hour. Each drying cylinder in the steam range makes 20 turns in the minute, with a diameter of 18 inches, or a circumference of 4½ feet; but 4½ × 20 = 90 feet per minute = 5,400 per hour = 1,800 yards. A common dressing machine does 10 pieces or cuts of 60 yards each in a day; which is at the rate of 3,600 yards in a week.

One of these machines made by Mr. Lillie for Mr. Waterhouse, an eminent manufacturer near Manchester, dresses, in 12 hours, 100 warps, each 370 yards long, which is no less than 37,000 in that time, being at the rate of 3,083 yards per hour, or 1¾ mile.

CHAPTER V.

Weaving.

Weaving is the art of making cloth by the rectangular decussation of flexible fibres, of which the longitudinal are called the warp or chain, and the transverse the woof or weft. The former extends through the whole length of the web, the latter only over its breadth. The outside thread on each side of the warp, round which the woof-thread returns in the act of decussation, is called the selvage or list.

In the earliest records of man we find this indispensable, though now vulgar, art, mentioned with the

highest honour; thus, in the book of Exodus, we read,—"With wisdom to work the work of a weaver;" and in the most ancient of books, one of its implements is elegantly used to illustrate a moral apothegm,—"My days are swifter than a weaver's shuttle."—*Job.*

The art of weaving is more ancient than that of spinning, for the first cloth was, no doubt, akin to what we call matting,—a texture formed by the interlacement of woody fibres, and of grasses of various kinds, as is still executed by several of the South Sea islanders. At the period of Captain Cook's voyages, most of them were strangers even to that rude art, for they made their cloth by cementing or stitching shreds together, rather than by any kind of decussation.

It was the art of spinning, however, which first gave value to the art of weaving, properly so called, by supplying it with threads of any desired length, strength, and flexibility, to be worked up into a cohesive and durable web. The cultivation of flax, and the conversion of its tough fibres into clothing, were known at a very remote period in Egypt; and we perceive, from the story of Penelope's web, how highly the art of weaving was esteemed in the heroic ages of Greece. It was long, however, before it spread into western Europe; for when Julius Cæsar invaded Great Britain, he found our ancestors unacquainted with the loom. The Romans introduced this implement along with the other arts of civilization, and soon succeeded in establishing its use extensively among their English subjects; for the "Notitia Imperii" makes mention of an imperial manufactory of woollen and

linen cloth at Winchester, for the use of the Roman army. The art of weaving, however, must have advanced much more rapidly among our neighbours on the Continent than in this kingdom; for a great part of the British wool was for a long time exported in the raw state, and brought back from the Low Countries in the form of cloth.

There is a curious allusion to fancy weaving in Bishop Aldhelm's book concerning "Virginity," written about the year 680. "It is not a web of one uniform colour and texture, without any variety of

Fig. [illegible].—Representation of ancient Distaff Spinsters, from Montfaucon.

figures, that pleaseth the eye, and appeareth beautiful, but one that is woven by shuttles, filled with threads of purple, and many other colours flying from side to side, and forming a variety of figures and

images in different compartments, with admirable art." One of the most curious specimens of this ancient figure-weaving and embroidery now extant, is that preserved in the cathedral of Bayeux. It is a piece of linen nineteen inches in breadth, by sixty-

Fig. [illegible].—Ancient Loom, from Montfaucon.

seven yards in length, and contains the history of the "Conquest of England by William of Normandy;" beginning with Harold's embassy in 1065, and ending with his death at the battle of Hastings in 1066. This extraordinary piece of work is supposed to have been woven by Matilda, Queen of William the Conqueror, and the ladies of her court; but it is indebted for what beauty it possesses, much more to the labours of the needle, than of the loom.

From the few monuments which exist of ancient weavers, it is not easy to form a distinct idea of the manner in which they formed their woollen and linen cloths. If we judge from the figures still extant of the fourth and fifth centuries, this art was one of extreme simplicity. We there see some women spinning, others smoothing out the web. Those who weave the tissue are represented standing.

"In the ancient "Virgil of the Vatican," supposed to be a manuscript of the fourth century, and which formerly belonged to the monastery of St. Denys, in France, a woman is exhibited at work on a piece of cloth; she is in an upright position, and makes use of a long rod for a shuttle, fig. 93. I leave it to the skilful in weaving to explain this mode of proceeding. Another manuscript of the "Bibliothèque du Roi," which is a commentary on the book of Job, has a figure of a weaver at work on his web; and he also is standing. Although this manuscript be only of the tenth century, the figures are copied from more ancient manuscripts; for, according to an ancient commentator, the oldest copies of the book of Job possessed these painted images, which have been transmitted in the later copies."—*Montfaucon*, iii. p. 358.

At so late a period as the year 1331, weaving was so little understood in England, that the arrival of two weavers from Brabant is recorded in the chronicles among the important events of the time. But it was the religious persecutions of the Duke of Alva which first gave importance to our cloth manufacture, by driving crowds of Flemish weavers to seek a home in this country. What one bigot had begun, another completed. Louis XIV., by his revocation of the Edict of Nantz, in 1686, caused the expulsion from France into England of about 50,000 of the best French manufacturers, many of them eminently skilled in the weaving of silk and other fine fabrics.

Fig. 84.—The Weaver, with his Wife fetching Woof, as figured in Schopfer's Panoplia—Frankfort on the Maine, 1568.

The process of *warping* always precedes weaving. Its object is to extend the whole number of threads, which are to form the chain of the web, alongside of each other in a parallel plane. As many bobbins are taken as will furnish the quantity of thread required for the length of the piece of cloth. The bobbins are usually one-sixth the number of all the threads, and are mounted loosely on spindles in a frame, so that they may revolve, and give off the yarn freely. The warper sits at A, fig. 95, and turns round the reel B, by the wheel C, and rope D. The yarn on the bobbins is seen at E. The slide F rises and falls by the coiling and uncoiling of the cord G, on the shaft of the reel H. By this simple contrivance, the band of warp-yarns is wound from top to bottom,

Fig. 95.—Hand-warping for the Muslin-weaver.

spirally, round the reel. I, I, I, represent wooden pins, similar to those used in peg-warping.

Most warping-mills are of a prismatic form; and have twelve, eighteen, or more sides. The reel is usually about six feet in diameter, and seven feet high, and serves to measure accurately, on its circumference, the length of the warp. It may be turned either way by a rope moved by the trundle C, which is actuated by the warper's hand. At E, is the frame to contain the bobbins, the threads from which pass through the heck placed at F. This now consists of a number of finely polished and hard tempered steel pins, with a small hole at the upper part of each to receive and guide one thread. The modern heck contains two parts, either of which may be lifted by a small handle below, and the eyes of each are alternately placed. Thus, when one is raised, a vacancy is formed between the threads, and when the other is raised the vacancy is reversed. By this the lease is formed at each end of the warp, and this is preserved by appropriate pegs. These being carefully tied up, give the rule for the weaver to insert his rods. The warping-mill is turned each way successively, until a sufficient number of threads are accumulated to form the breadth wanted. The warper's principal care is to tie immediately every thread as it breaks, otherwise deficiencies in the chain would exist, highly detrimental to the web, or productive of great inconvenience to the weaver. The box which contains the heck slides on an upright rod, as shown in the figure.

The simplest, and probably the most ancient, loom is the Indian. It consists of two bamboo rollers,—one for the warp, and another for the woven cloth, and a

pair of heddles for parting the warp in the decussation of the woof. The shuttle performs the double office of shuttle and lay for driving home the parallel yarns. It is made like a large netting-needle, and rather longer than the intended breadth of the cloth. The Tanty carries this rude apparatus to any tree

Fig. [illegible].—Indian Tanty, from a Plate in Solvyn's "Hindoos."

which may afford a comfortable shade: here he digs a hole large enough to receive his legs and the lower part of the geer or treddles; he then stretches his warp by fastening his two bamboo rollers, at a proper distance from each other, with pins into the turf; the heddles he fastens to some convenient branch of the tree overhead; he inserts his great toes into two loops under the geer to serve him for treadles; he finally, sheds the warp, draws the weft, and afterwards strikes it up close to the web with his long shuttle, which thus performs the office of a batten.

Fig. 97 exhibits our loom in its plainest state. The

Fig. 97.—Common Fly-shuttle Loom.

warp is wound about the beam A; the lease is preserved by the rods at B; and the two heddles or healds at C, consist of twines looped in the middle, through which loops the warp-yarns are drawn, one-

half through the front heddle, and the other through the back one. The yarns then pass through the reed under D, fixed in a movable swinging frame E, called the batten, lay, or lathe. This lay is suspended to a cross-bar F, attached to the upper part of the side uprights, so as to vibrate upon it. The weaver sits on the board G, presses down one of the treddles at H with his foot, which raising one of the heddles and sinking the other, sheds the warp by lifting and depressing each alternate thread a little way: a pathway is thus opened for the shuttle to traverse the warp. The weaver holds the picking-peg I, in his right hand, and by a smart jerking motion drives the shuttle swiftly from one side of the loom to the other, between the warp-yarns. The shuttle having left behind it a shoot of weft, between the reed and the weaver, he now pulls the lay, with its reed, towards him with his left hand, so as to drive home the weft-yarn to the web, made by the preceding casts of the shuttle. The cloth is wound upon the cloth-beam over I, in proportion as it is wove.

An accurate representation of the most improved kind of shuttle, furnished with friction wires, is given under power-loom weaving, page 296. As the shuttle darts across the warp, the weft-yarn uncoils from its cop or pirn, and runs through a small hole in the side of the shuttle.

The mode of throwing the shuttle by the jerk of a picking-peg and cord is a great improvement on the old way of throwing it from the hand. It was invented in the year 1738 by Mr. John Kay, a native of Bury in Lancashire, who was at that time resident in Colchester. It enabled the weaver to make nearly

double the quantity of cloth in the same time, and of any requisite width.

One might imagine that the author of this elegant invention, so well calculated to lighten the drudgery, and facilitate the gains of his fellow operatives, would have obtained favour in their eyes, at least, if not some recompense; but, alas! Kay shared the too-common fate of the real benefactors of his race. He was persecuted as a dangerous innovator, who, in showing how brute labour could be spared, might possibly diminish the demand for workmen. He was driven by cabals and mobs from his native land,—forced to live and die a sad exile in Paris.

John Kay brought this contrivance to his native town in the above year. It was adopted by the woollen weavers immediately, but was little used by the weavers of cotton goods before the year 1760. In that year Mr. Robert Kay, of Bury, son of the preceding, invented the drop-box, by means of which the weaver can, at pleasure, use any one of three shuttles, each containing a different coloured weft, without the trouble of removing them from the lay.* *See* fig. 98.

As soon as a few inches of cloth are woven they are wound upon the cloth-roll, by putting a short lever into a hole in the end of that roll, and turning it round, while a click, resting in the teeth of a ratchet-wheel on the cylinder, prevents its return. The cross-sticks at B are smooth, and usually three in number. Being put between the warp-yarns, they preserve the lease and keep the threads from entangling. They are maintained at a uniform distance from

* Mr. Guest's compendious History of the Cotton Manufacture, p. 8.

the heddles, either by tying them together, or by a small cord with a hook at one end which lays hold of the front rod, and a weight at the other which hangs over the yarn-beam. The cloth is kept extended during the operation of weaving by means of two pieces of hard wood, called a templet, furnished with sharp iron points in their ends, which take hold of the opposite edges or selvages of the web. These two pieces are bound together by a cord, which passes obliquely through holes or notches in each piece. By this mode of connexion the templet can be lengthened or shortened according to the width of the cloth. After the proper degree of extension is given, the two parallel bars of wood are kept flat on the cloth by a small cross bar, which turns on a peg fixed in one of the bars, (*see* power-weaving, p. 287.)

The perfection of weaving depends very much upon the warp being extended in the loom in a parallel plane, with an equal tension. In setting the lease-rods, care must be taken that all the threads which are to go through one of the heddles be separated by these rods from the threads belonging to the other heddle. This separation is originally made in the warping-mill by means of the heck.

The operation of *beaming* the warp requires particular care to insure good cloth. When the weaver receives his warp in a large ball or bundle, he proceeds to roll it regularly upon the yarn-roller of his loom. In this process he employs an instrument called a separator or ravel, composed of a number of shreds of cane, fastened together by means of a rail of wood, like the teeth of a long comb. The threads are to be inserted into the spaces between these teeth, so as to

spread the warp to its proper breadth. Ravels resemble reeds, but they are coarser, and of different dimensions. A ravel proper for the purpose being chosen, one of the small divisions of the warp is placed in every interval between two of the teeth. The upper part of the ravel, called the cape, is then put on to secure the threads from getting out between the teeth, and the operation of winding the warp on the beam now commences. After the warp is wound upon the beam, the operation of drawing is performed, which consists in passing every thread through its appropriate eye or loop in the heddles. Two rods are first inserted into the lease formed by the pins in the warping-mill; and these rods being tied together at the ends, the twine by which the lease was secured is cut away, and the warp is stretched to its proper breadth. The yarn-beam is suspended by cords behind the heddles, somewhat higher, so that the warp hangs down perpendicularly. The weaver places himself in front of the heddles, and opens the eye of each heddle in succession, while an assistant, placed behind the heddles, selects every thread in its order, and presents it to be drawn through the open eyes of the heddles. The succession in which the yarns are to be delivered is easily determined by the lease-rods, as every thread crosses that next to it. The warp, after passing through the heddles, is drawn through the reed by an instrument called a sley, or reed-hook, and two threads are taken through every interval in the reed.

The lease-rods being passed through the intervals which form the lease, every thread will be found to pass over the first rod, and under the second; the

next thread passes under the first, and over the second; and so on, alternately. By this method every thread is kept distinct from the one on either side of it, so that, if broken, its true situation in the warp may be found at once. There is likewise a third rod which divides the warp into what is called *splitfuls*, for two threads pass alternately over and under it; and these two threads also pass through the same interval betwixt the splits of the thread.

The cords or mounting which move the heddles are now applied; the reed being placed in the lay or batten, the beginning of the warp is knotted together into small portions, which are tied to a shaft and connected by cords with the cloth-beam; and the yarns are finally stretched in order to begin weaving.

The operations of common weaving are simple, and soon learned, but require much practice to be performed with dexterity. In pressing down the treadles of a loom, most beginners are apt to apply the weight or force of the foot much too suddenly. The ill effects of this sudden pressure are particularly obvious in weaving fine or weak cotton yarns; for the body of the warp must thereby sustain a stress nearly equal to the force with which the foot is applied to the treadle. Moreover, every thread is subjected to all the friction occasioned by the heddles and splits of the reed, between which it passes, and with which it is brought in contact when rising and sinking. As it is difficult to make yarns equally strong and tight, some will be more affected than others by undue or sudden pressure, and be occasionally broken. Even with the greatest care, more time is lost in tying or

replacing these warp-yarns, than would have been sufficient for weaving a considerable piece of cloth.

Should the weaver, from negligence, continue the operation after one or more warp-threads are broken, the cloth will be seriously damaged. The broken thread does not retain its parallelism to the rest, but crossing over or between those nearest to it, either causes them also to break, or interrupts the passage of the shuttle. In every kind of weaving, also, but especially in thin wiry fabrics, such as book-muslins, much of the beauty of the goods depends upon the weft being in a proper state of tension. If the motion given to the shuttle be too rapid, it is very apt to recoil, and to slacken the thread. It has also a greater tendency either to break the weft altogether, or to unwind it from the pin of the shuttle in doubles, which, if not picked out, would disfigure the fabric. The weft of thin cotton goods is sometimes woven wet into the cloth, the moisture tending to lay the ends of the cotton filaments smooth or parallel.

In the common operation of weaving, the proper force of stroke for beating up the weft-yarn must be learned by practice. The weaver ought, however, to mount his loom in such a manner that the swing or vibration of the lay may be proportional to the thickness of the cloth. As the lay oscillates backwards and forwards upon centres placed above, its motion is similar to that of a pendulum. The greater, therefore, the arc through which the lay moves, the greater effect will it have in driving home the weft, and the thicker the fabric will be, as far as the weft is concerned. Hence in weaving coarse and heavy goods,

the heddles ought to be hung at a greater distance from the place where the weft is struck up, and consequently where the cloth begins to be formed, than it should be for light goods. The line of the last wrought shot of weft is called by weavers the *fell*. The pivots on which the lay swings ought in general to be so placed that the reed will be exactly in the middle between the fell and the heddles, when the lay hangs perpendicularly. As the fell constantly varies its position, the medium distance should be taken, or the place where the fell will be when half as much is woven as can be done without winding it on the cloth-roll, and drawing more warp from its cylinder.

The intervals for taking up the cloth should always be short in weaving light goods, for the less the fell varies from the medium, the more regular will be the impulsion of the lay. Mr. Hall obtained a patent, in 1803, for a method of continually turning round the cloth-beam, so as to wind up the cloth as fast as it was woven, or even shot by shot. This was effected by a ratchet-wheel fixed on the end of the cloth-beam, and a catch or detent to move it round one tooth at a time. This catch was actuated by the impulsion of the lay. Similar contrivances are now universally adopted in power-loom weaving.

Dressing a web, is the application of flour paste to the warp with a brush, in order to smooth down all the loose filaments of the yarn, as well as to increase its stiffness and tenacity. In applying the dressing, the weaver suspends the labour of the shuttle whenever he has worked up the portion of warp already dressed, applies the comb to clear away knots and burs, then pushes back the lease rods towards the yarn

beam, and, lastly, brushes the yarn with the paste by two brushes, holding one in each hand. The superfluous humidity is afterwards removed by winnowing the warp with a large fan. A small quantity of grease is occasionally brushed over the yarn, the lease-rods are restored to their proper places, and the loom is put in action. The preparation of paste or size for weavers' dressing has been the subject of several patents. Mr. Foden recommends a quantity of calcined gypsum to be reduced to a fine powder, mixed with alum, sugar, and the farina of starch or potatoes, the whole to be made into a thin paste with cold water, and the mixture afterwards boiled to a gelatinous consistence.

Peter Marsland, Esq., of Stockport, obtained a patent in 1805 for an ingenious method of starching cotton yarn in the cop, so that it might be ready for weaving whenever it was warped. He placed the cops in a tight vessel, exhausted the air, and then admitted the hot paste in a liquid state. By this elegant physical device, he caused the cotton fibres to be thoroughly impregnated into the very heart of the cops. It was found, however, difficult to dry the cops thereafter, and to transfer their yarns to the warp-mill bobbins.

In the specifications of some throstle-spinning patents, it is proposed to give the yarn a dressing before it is wound upon the bobbin by making it pass between a pair of rollers immersed in a trough filled with paste. Cop-yarn is sometimes passed over a cylinder revolving in a paste-box during the process of reeling it on the bobbins of the warping-mill.

For the insertion of wefts of different fineness, or of different colours, into one web, different shuttles must be in readiness for alternate use. With this view, an

apparatus of movable shuttle boxes is attached to each end of the lay, as is represented at D in fig. 98. Here are seen three boxes so constructed as to slide up and down in a vertical plane. They are suspended by a cord from the cross levers G, G, which turn upon centres in the suspending bars or swords of the lay, marked B, B. A represents the cross spar of wood on which the lay oscillates upon iron gudgeons or

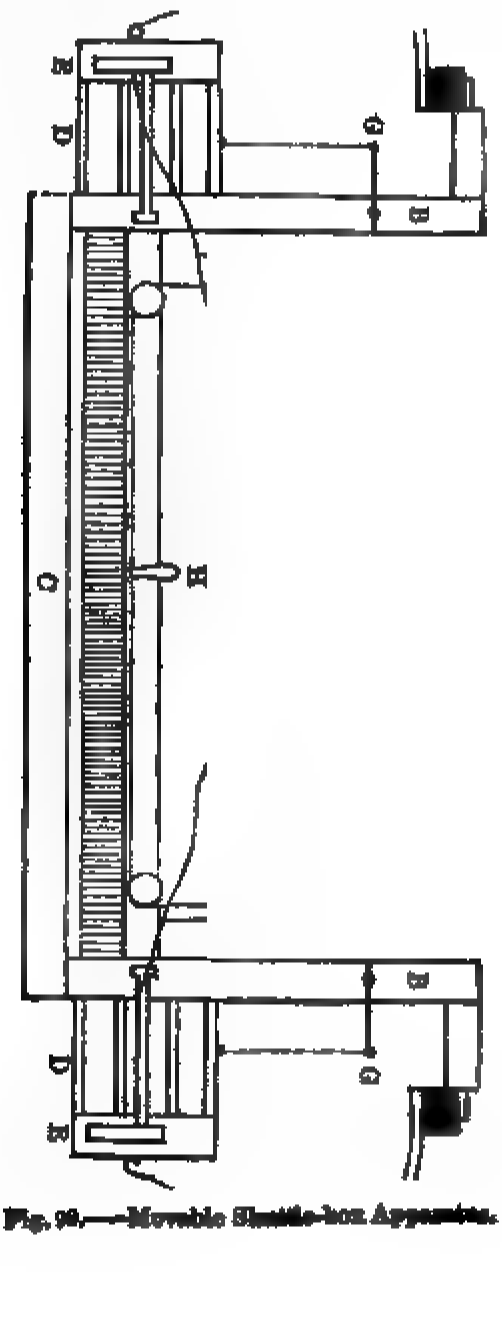


Fig. 98.—Movable Shuttle-box Apparatus.

pivots driven into each of its ends, and resting upon the upper rails of the loom, as shown in section. The under part of the lay appears at C, and the upper bar or lay-cap H, which the weaver seizes in his hand in driving home the weft. Above E, E are seen the two pieces of wood called drivers or peckers, which traverse horizontally upon smoothly polished iron rods, and which give motion to the shuttle. These drivers are impelled by the jerk of the weaver's hand, and the impulse must be so smartly given as to communicate adequate velocity to lodge the shuttle in the opposite box, overcoming the friction of the shuttle along the warp-race.

The pin H is made to slide freely from right to left on the upper bar of the lay, whereby the levers G are moved at pleasure, and any one of the three boxes brought opposite the driver. F is the pecker handle.

When the pattern of the cloth is to be diversified, a single pair of alternate heddles and levers becomes inadequate to the work, and several heddle-leaves must be introduced into the loom. Every leaf is suspended from a particular lever above, connected by a cord with the march-bars below, and thence with a corresponding series of treadles. Such an apparatus will afford a comprehensive range of patterns; but the draw-loom must be had recourse to for fancy work in general.

Fig. 99. This wood-cut exhibits the outline of a loom mounted with several heddle-leaves. Instead of the jacks which lift the heddle-frames in the plain loom, levers, such as are shown at A, A, are used, one of which suspends every leaf of the heddles. From the ends of these levers a connexion is formed by a cord with the marches at B, of which there are two sets, diverg-

ing from the centre of the loom to either extremity. In order that every treadle may operate equally on both sides, the spring staves C, C, are used, from which the connexion is established with the treadles at D. When a heddle is depressed, this part of the apparatus will raise the leaf or leaves with which it is connected,

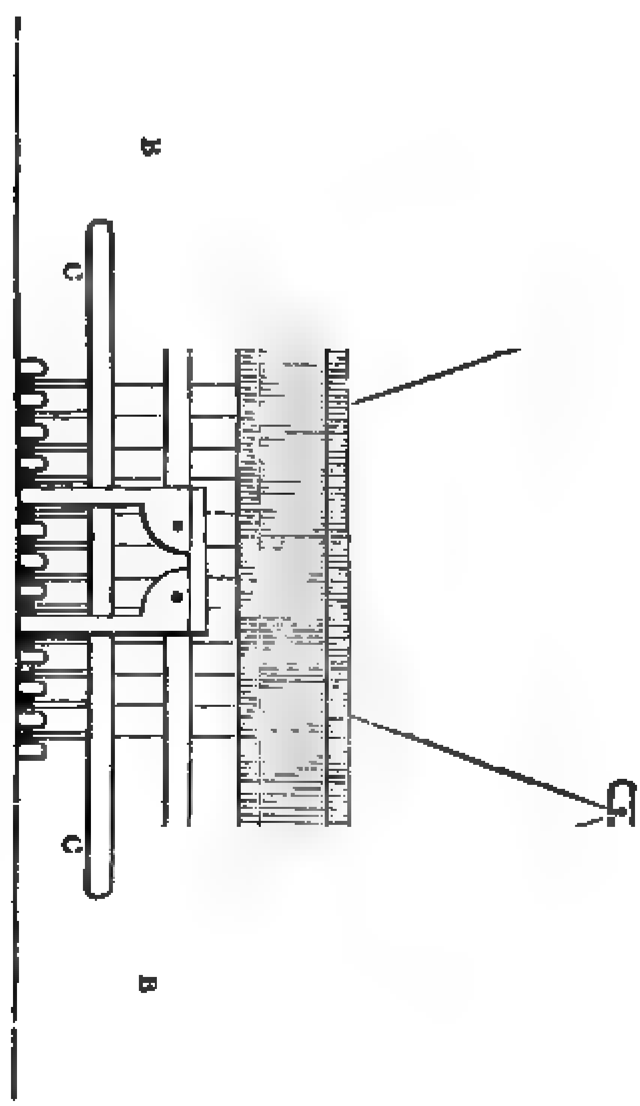


Fig. 90.—Loom with several Heddle-leaves.

and, by direct communication from the heddles, the sinking is produced.

Figures or patterns are produced in cloth by employing threads either of different colours, or of different texture, in the warp or weft. In weaving, the threads must be so disposed that some colours will be concealed and kept at the back, whilst others are placed in front; and they must occasionally change places, so as to show as much of each colour or texture as is requisite to make out the figure or pattern. The weaver has three means of effecting such changes of colour or appearance.

First, by using differently coloured threads in the warp, or threads of different sizes and substances; these are arranged in the warping, and require no change in the manner of weaving. This style is confined to patterns, with stripes in the direction of the length of the piece. Secondly, by employing several shuttles charged with threads of different colours or substances, and changing one for another every time that a change of colour or appearance is required. This plan makes stripes across the piece; or if combined with a coloured warp, it makes chequered and spotted patterns of great variety. Thirdly, by employing a variety of heddle-leaves, instead of two, each heddle having a certain portion of the warp allotted to it, and provided with a treadle. When this treadle is pressed down, only a certain portion of yarns which belong to its heddle will be drawn up, and the rest will be depressed; consequently, when the weft is thrown, all those yarns which are drawn up will appear on the front or top of the cloth; but in the intervals between them, the weft must appear over those warp

threads which are depressed. The number of threads which are thus brought up may be varied as often as the weaver chooses to press his foot upon a different treadle, and thereby he produces his pattern. When all these three means are combined together, they afford the weaver ample resources for representing the most complicated patterns.

Tweeled and figured cloths are so various in their textures, and so complex in their formation, that it is difficult to convey an adequate idea of the modes of constructing them without entering into lengthened descriptions incompatible with the limits of this work. In examining any piece of *plain* cloth, it will be observed that every thread of the weft crosses alternately over and under every thread of the warp in its decussation; and the same may be said of the warp. In short, the warp and weft-yarns are thus interwoven and tacked at every individual thread. In *tweeled* cloth only the third, fourth, fifth, sixth, &c., threads interlace each other to form that peculiar texture.

Figure 100 represents a section of tweeled fabric. The warp is shown by the round dots. Here four of the successive threads of the warp will be found to pass over or under the same thread of the weft; or, in other words, by tracing any thread of the weft, it will be found to pass over four threads of the warp. Then it crosses and passes between the threads of the warp, and proceeds beneath four more threads, before it makes another intersection between the threads of the warp. By this means the warp-yarns get con-

Fig. 100.—Dimity, Diaper, Kerseymere.

densed so as to thicken the fabric. The tweeled fabric is also ornamental, from the figure being capable of inversion at pleasure. Thus there are four threads passed over in this pattern, and one only intersected; of these four threads, the series marked 1 and 2 are under the weft-line, while those marked 3 and 4 are above it. This does not affect the solidity or strength of the texture, but is merely subservient to ornament. At all the intersecting points where the threads actually cross or interweave, both threads of warp and weft are seen together, and these points are therefore more marked to the eye, even if the warp and the weft are of the same colour. In plain tweels these points form parallel lines extending diagonally across the cloth, with different degrees of obliquity, according to the number of weft-threads over or under which the warp-threads run before an intersection takes place. In the coarsest kinds every third thread is crossed; in finer fabrics, each sixth, seventh, or eight thread is crossed. In some fine tweeled silks the crossing does not take place until the sixteenth interval.

The art of adapting those parts of a loom which move the warp to the formation of various kinds of ornamental figures upon cloth is called by weavers *draught and cording*. In every species of weaving, whether direct or cross, the whole difference of pattern or effect is produced either by the succession in which the threads of warp are inserted into the heddles, or by the succession in which those heddles are moved in the working. The heddles being stretched between two shafts of wood, all the heddles connected by the same shafts are called a leaf, and as the operation of introducing the warp into any number of leaves is

called *drawing a warp*, the plan of succession is called the *draught*. When this operation has been performed correctly, the next part of the weaver's business is to connect the different leaves with the levers or treadles by which they are to be moved, so that one or more may be raised or sunk by every treadle successively, in the order suitable to the particular pattern.

As these connexions are made by coupling the different parts of the apparatus with cords, the name of *cording* is given to this operation. In order to direct the operator in this part of his business, especially if previously unacquainted with the particular pattern upon which he is to be employed, plans are drawn upon paper similar to that represented in the wood-cut.

Fig. 101 is the horizontal section of a loom, the heddles being represented across the paper at A, A, and the treadles under them, and crossing them at right angles as at B, B. They are represented as distinct pieces of wood, those across being the under shaft of each leaf of heddles, and those at the left hand the treadles. In the actual loom the treadles are placed at right angles to the heddles, the sinking cords descending perpendicularly, as nearly as possible to the

B

A

5 4 3 2 1 C C C

B

Fig. 101.—Five-leave Tweel.

centre of the latter. Placing them at the left in the plan, therefore, is only for ready inspection and practical convenience. At C a few threads of warp are shewn as they pass through the heddles, and the thickened marks denote the leaf with which each thread is connected. Thus the right-hand thread next to A, passes through the eye of a heddle upon the back leaf, and is unconnected with all the other leaves; the next thread passes through a heddle on the second leaf; the third through the third leaf; the fourth through the fourth leaf, and the fifth through the fifth, or front leaf. One set of the draught being now completed, the weaver begins again with the back leaf, and proceeds in the same succession to the front one.

Two sets of the draught are represented in the figure, and the same succession must be repeated till all the warp is included. Weavers understand this, and seldom delineate more than one set. When they proceed to apply the cords, the left-hand part of the plan at B serves as a guide. A connexion must be formed by cording, between every leaf of heddles and every treadle, for all the leaves must either rise or sink. The rising motion is effected by joining the leaf to one end of its correspondent top-lever; the other end of this lever is tied to the long march (*step*) below, and this to the treadle, fig. 99. The sinking connexion is carried directly from under the leaf to the treadle. In order to direct the weaver which of these connexions is to be formed with each treadle, a black dot is placed when a leaf is to be raised, where the leaf and treadle intersect each other upon the plan; and the sinking connexions are left blank. For example, to cord the treadle 1, put a raising-cord to the back leaf, and four

sinking cords to each of the other. For the treadle 2, raise the second leaf and sink the remaining four, and so of the rest, the dot always denoting the leaf or leaves to be raised. The figure is drawn for the purpose of rendering the general principle of this kind of plans familiar to those who have not been previously acquainted with them; but those who have been accustomed to manufacture or weave ornamented goods never take the trouble of representing either heddles or treadles as solid or distinct bodies. They content themselves with ruling a number of lines across a piece of paper, sufficient to make the intervals between these lines represent the number of leaves required. Upon these intervals they merely mark the succession of the draught, without producing every line to resemble a thread of warp. At the left hand they draw as many lines across the former as will afford an interval for each treadle, and in the squares formed by the intersections of these lines they place the dots, spots, or cyphers, which denote the rising cords. It is also common to continue the cross lines which denote the treadles a considerable length beyond the intersections, and to mark by dots placed diagonally in the intervals the order, or succession, in which the treadles are to be pressed down in weaving.

Figure 100 represents the regular, or run-tweel, which, as every leaf rises in regular succession while the rest are sunk, interweaves the warp and woof only at every fifth interval; and, as the succession is uniform, the cloth when woven presents the appearance of parallel diagonal lines at an angle of about 45° over all the surface. When there is no other figure upon the cloth and the fabric is fine, this produces a very

pleasing effect, and is much used. The wood-cut, figure 101, represents the draught and cording of striped dimity of a tweel of five leaves. This is the most simple species of fanciful tweeling. It consists of ten leaves, or double the number of the common tweel. These ten leaves are moved by only five treadles, in the same manner as a common tweel. The design is formed by one set of the leaves flushing the warp, and the other set the weft.

Here the stripe is formed by ten threads, alternately drawn through each of the two sets of leaves. In this case the stripe and the intervals will be equally broad, and what is the stripe upon one side of the cloth will be the interval on the other, and conversely. Great varieties of patterns may be introduced by drawing the warp in greater or smaller portions through either set. The tweel is of the regular kind, but may be broken by placing the cording spots alternately. The cording marks of the lower, or front leaves, are exactly the converse of the other set, for where a raising mark is placed upon one, it is marked for sinking in the other; that is to say, the mark is omitted, and all leaves which sink in the one are marked for raising in the other; thus, in the back set one thread rises in succession and four sink; but in the front set four rise and only one sinks. The weft passing over the four sunk threads and under the raised one, in the first case is flushed above, but in the second the reverse occurs, or it is flushed below, and thus the appearance of a stripe is given.

Among the varieties of texture produced by the loom that of common gauze, or *linau*, a substance much used for various light purposes, deserves to be

explained. A section of its web is represented in fig. 102. The essential difference between this fabric and those hitherto described consists in the warp being twined or twisted like a rope during the operation of weaving, whereby the cloth acquires a considerable resemblance to lace. The twisting of the warp by the

Fig. 102.—Common Gauze.

working of the heddles is not continued in the same direction, but is effected alternately from right to left and from left to right, between every intersection of the weft. The texture of gauze is always open, flimsy, and transparent, but from the twining of the warp it possesses an uncommon degree of strength and tenacity, in proportion to the quantity of materials which it contains. This quality, together with its transparency, fits it for ornamental purposes of various kinds, particularly for flowering or figuring either with the needle or in the loom. In the warp of gauze a much greater degree of contraction takes place during the weaving than in plain or tweeled goods, where no such twist is given to the warp yarns. By inspecting the figure it will be seen that the twisting between every intersection of weft amounts to one complete revolution of two contiguous threads. Hence *linau* possesses this peculiarity, that the same thread of warp is always above the weft in the loom, and the adjoining thread is always below it.

The draw-loom is one of the most complete and intricate machines used in the weaving of ornamental cloth. There is no variety of pattern or figure, however extensive, which can be brought within the range of cloth

of the largest dimensions but may be produced by this multiform, though costly apparatus. Draw-looms are used for three purposes in this country—for weaving spotted muslins, damasks, and carpets. The general principles of the construction are in all cases the same, but they are modified according to the specific application. When patterns become so diversified that the number of heddles necessary for moving the warp in its configurations could neither be included within any moderate bounds, nor worked by any ordinary power, recourse must be had to the draw-loom. Of all the machines of this kind, that for weaving damasks is the most complicated; in some cases it contains 120 designs of ten spaces each, a number equivalent to 1,200 leaves of the diaper-heddle harness, or 6,000 of the leaves such as are used for dimity or common tweeling. The general principle of the draw-loom harness, and the mode by which the flushing is reversed, is in every respect the same as that of the diaper, the difference consisting solely in the greater capabilities of the draw-loom, and the method of mounting and working it.

The wood-cut, fig. 103, shows a perspective view of the harness part of a draw-loom, and of the apparatus for working it. The harness cords of a draw-loom are of necessity so numerous and so closely crowded together, that any representation of the whole, even upon a very large scale, must convey an inadequate idea of their structure and operation. A few, therefore, only, are here exhibited at intervals to illustrate the mode of constructing them; and the principle being once well understood, may be extended to any number that convenience will admit. The harness of the draw-loom is not confined by leaves, but every cord carries

a mail or loop for the warp, and is kept stretched by a weight. The weights attached to the harness are represented at L. A horizontal board or frame, C, is fixed across the loom, and is either perforated with a number of small holes, or is divided by wires or pins, to serve as guides to the cords of the harness that pass

Fig. 108.—Draw-Loom.

through them. When the range or extent of the design has been ascertained, by counting on the design-paper the greatest number of squares contained in it from right to left, the harness must be made to correspond with this range. Let the range be supposed to extend to 500 squares, and the whole breadth of the warp to contain 10,000 threads. If five threads are to be drawn through each mail, the number of mails composing the harness will be 2,000, and four ranges of the pattern will comprehend the whole breadth. The divisions in the board C, and the number of pulleys in the box or case H, being adapted to this, the operator may proceed to put up his harness, which is done as follows:—The 1st, 501st, 1,001st, and 1,501st harness-twines, after being passed through their respective intervals in the board or frame C, are to be knotted together at M. A cord being attached to these, is carried over the first pulley in the case H, and is made fast to the piece of wood G, which is commonly called the *table*. The 2d, 502d, 1,002d, and 1,502d are next connected in the same way, and the cord attached to them, passing over the second pulley, is fastened to the table as before. The same operation is successively carried on until the whole 500 connexions are completed. The cords at B passing over the pulleys and fastened to the table are called the *tail* of the harness. From each cord in the tail a vertical cord descends, and is made fast to a piece of wood, K, which is lashed to a fixture in the floor. These cords, represented at D, are called *simples*. The draught of the warp through the mails of the harness is regularly progressive from right to left as in common tweeling, and the draught cording and mounting

of the front leaves are exactly the same as in diaper. A stout cord is now stretched perpendicularly from the roof to the floor, and made fast at both ends. This cord is seen at I. The loom is now ready to be adapted to work to any pattern of the range of 500 squares or mails.

The next operation, therefore, is to apply a certain number of small cords, called *lashes*, as shewn at E, in order to form the particular pattern required. This is called reading on the design, and from its complexity, and the injurious consequences of a slight error, it is performed by two persons in concert. The first individual selects from the design-paper the simples to which lashes are to be applied in succession, and the second applies these lashes according to the instructions communicated by the first. In reading or selecting the lashes in their proper rotation they should bear in mind that the whole range of squares from right to left, between the extreme points of the pattern, is equal to the number of simples, and the whole range from top to bottom is equal to the number of operations which those simples are to undergo. The person who is to select takes, therefore, the design-paper, begins at the lowest square, and, counting from the right hand, instructs the other to pass as many simples as there are blank squares upon the paper, to put lashes to as many as are coloured, again to pass over the blanks, to take the coloured squares, and so on till he has reached the left side of the pattern. When these lashes have been applied, which is done by passing each loosely round the simples which it is to work, they are knotted together, and attached to the cord I, by a loop, so that they may slide up and

down freely, both upon the cord and the simples. Proceeding to the second square from the bottom, the selection is made in the same way, and thus they continue until they have reached the top. The lashes being now in clusters upon the cord I, these clusters are connected at convenient distances from each other by small cords represented at F, the first applied cluster being the lowest upon the cord I.

The draw-loom being now ready for work, the operators may begin to weave; two persons being required to work the machine. One of them pulls down the first set of lashes, the whole of which are placed high upon the cord I, and, by pulling them tight, he draws the simples with which they are connected clear of all the rest. Then by grasping these simples firmly in his hand, and pulling them down, he tightens the tail-cords at B by making them diverge more from a straight line, and of course raises the mails which are attached to them by the harness-twines at M. The weaver then works over his front mounting, as in common tweeling, once or oftener, if more squares than one upon the design-paper are included between the same parallel straight lines from top to bottom. When a change of the harness becomes necessary, the connecting cord F pulls down the second cluster of lashes, upon which the same operation is performed as before. By these means, the simples, however numerous (and in the case we have supposed, they would amount to 500) are selected from each other with the greatest accuracy and ease. The successive performance of the same operation completes the pattern; when it is necessary merely to push the lashes up again and begin a new one.

In the harness of the spot draw-loom for muslins, as the warp is slender, short eyes of twine are substituted for the mails of wire. In the front mounting also, four leaves of heddles are used; but they are so mounted, that two leaves will go together either up or down, or in opposite directions. The heddles are constructed like those for weaving plain cloth, and every thread is drawn through two heddles, being taken through the upper cleft or link of the one, and through the under link of the other. When the two leaves move in the same direction, the threads of warp are confined as in the clasp of a common heddle; but when they move in a contrary direction, they present all the facility of the long eye in allowing the thread to rise without interruption.

Power-Loom or Automatic Weaving.

Without tracing minutely the first rude steps of this factory child, we shall proceed to describe the grandeur of its present state. Continuity of action is an essential principle of all mechanisms impelled by the force of steam or running water; while alternate effort and repose are the characters of human labour. Hence the interruptions in the movements of the shuttle which take place while the weaver is dressing a certain portion of the web, and which serve to diversify his labour, would be intolerable in a factory where power and time must be economized to the utmost. It became, therefore, a matter of primary importance to combine with the automatic loom an automatic dressing machine. By the commencement of this century, the mechanism of the power-loom had been so far perfected by rival inventors as to demon-

strate its practical value, provided a good system of dressing the chain or warp could be devised. This want was not long of being supplied. In the year 1804, Mr. Johnson, of Stockport, obtained a patent for a method of dressing a whole web at once by a self-acting machine. An improvement was made upon it by Mr. MacAdam in 1806, which was immediately realized on a considerable scale in Mr. Monteith's weaving factory at Pollockshaws, near Glasgow. This was probably the first web-dressing mechanism which continued to give satisfaction to the manufacturer during a series of years.

Certain defects in this apparatus were, after a little while, removed by the warp-dressing machine of Messrs. Ross and Radcliffe, of Stockport. The Chamber of Commerce, of Manchester, were so much convinced of the value of the improvements introduced by these gentlemen, that they forwarded a memorial to the Lords of the Treasury soliciting a reward to the ingenious inventors. They here state "that the effects of the new method have been to bring the whole process of the manufacture (of cotton) from the raw material to the cloth into one connected series of operations, by means of which a cheaper, more uniform, and better fabric has been produced. That for introducing this greatly improved system the public is indebted to the persevering efforts of Messrs. Radcliffe and Ross, of Stockport, who, it appears, had expended their whole capital in bringing it to maturity, and were, in consequence, unable to remunerate themselves by the use and application of their own plans. That Messrs. Radcliffe and Ross are, therefore, in the opinion of your memorialists, justly entitled to be recompensed

by the public for the advantage derived from the adoption of this system." From a letter addressed to he Lords of the Treasury by Mr. Radcliffe, in June, 1825, it would appear that the prayer of the above memorial was unsuccessful.

We now proceed to describe the power-loom in its most practicable state, as constructed by the celebrated mechanicians, Messrs. Sharp and Roberts, of Manchester. It has taken no less than a century and a half to mature this admirable substitute for one of the most irksome but indispensable labours of man. Desgennes announced in the "Philosophical Transactions," so long ago as the year 1678, that he had contrived an automatic loom, possessing, as he thought, all the qualities only now realized; so great is the interval often between the speculative idea of a machine, and its effective execution, in consequence of the delicate compensations and adjustments which experience alone can discover. It was not till Horrocks, of Stockport, in 1813, after a long, laborious, and most costly career of experiment*, introduced some very important modifications into the power-loom, that it began to act any considerable part in our cotton manufacture. Horrocks, however, did not reap the reward due to his ingenuity, having omitted certain minutiæ in the construction of his machine, which interfered with its uniformity of performance, and thus allowed the prize of excellence to be won by his successors. His power-loom is described with figures in the Repertory of Arts and Manufactures for the year 1814. On that basis

* He had obtained one patent for a power-loom in 1803, and another in 1805.

Messrs. Sharp and Roberts have made their accomplished mechanism.

Towards the end of the year 1829, M. Emile Dollfus, as chairman of their committee of mechanics, made to the Société Industrielle of Mulhausen an interesting report, replete with new and valuable experimental facts, upon the different power-looms then employed in the cotton factories of Alsace. This report was published in the bulletin of the society for the year 1830, accompanied with several plates representing the ingenious power-looms of M. Josué Heilmann, M. Jourdain, MM. Risler and Dixon, and finally that of Messrs. Sharp and Roberts, as constructed in the great workshops of MM. André Kœchlin and Company, at Mulhausen.

One new feature of Mr. Horrocks' loom was the lathe being made by compound levers to advance quickly so as to give an effective stroke to the weft, and then to retire quickly to a stationary position. By this means, the shuttle was allowed to pass through the shed while the lathe was standing still; a larger shuttle might be used, capable of holding a full-sized cop; the waste of weft from the bottoms in the cops became less; from the smartness of the stroke, less weight for tension was required upon the yarn-beam, and therefore less power was required to move the healds or heddles from the smaller tension of the warp. From this cause, also, less moving force would be expended, fewer threads would break in the working, and more threads of the weft could be condensed into the inch, making a stronger and more uniform fabric.

Description of Sharp and Roberts' improved Power-Loom.

Figs. 104 and 106 are two side elevations; and fig. 105 is a front view.

Those parts in the engravings marked with the letter A, compose the frame-work of the loom. B is the usual outrigger, or fast and loose pulleys, upon the principal or crank shaft. C is a small fly-wheel for equalizing any casual irregularities of motion in the machine.

Upon the other end of the main shaft is a wheel, D, figs. 105 and 106, driving another wheel, D′, with double the number of teeth, upon the shaft, E, which makes, therefore, only half as many revolutions as the main or crank shaft, B. The shaft, E, is called the tappet or wiper-shaft: it raises and lowers the treadles, and throws the shuttle, while the shaft, B, by means of its cranks, F, figs. 104 and 106, drives home the weft towards the finished cloth, or works the batten.

The cranks, F, are connected with the two levers, G, G, called the swords of the lay, to which the batten H is made fast, which carries the reed in its middle, and the shuttle-boxes, *h*, *h*, at its ends, see fig. 105.

I is the warp-beam. The warp-yarns pass from it over the roller, K, through the heddles L, through the reed *l*′, over the breast beam M (having been now changed into cloth). This is finally wound upon the roller, N, or cloth-beam. This roller bears at one end a toothed wheel, *a*, which is moved slowly by a small pinion, *u*, (fig. 104) upon the axis of the ratchet-wheel, *b*. This latter wheel is turned round a little after every throw of the shuttle, or shoot of the weft, by means of a

stud, c, (figs. 105 and 106), fixed upon the side of the lever, G, and pressing against the other lever *d*, with which a click is connected. The degree of motion of the ratchet is regulated according to the quality of the cloth, by fixing the click in different holes of the (dotted) lever, *d*. The lifting of the heddle, L, is performed by two

Fig. 104.—Sharp and Roberts' Power-Loom. First side elevation. Scale, one inch to the foot.

tric tappets or wipers, O, O′, upon the shaft, E, press the treadle-levers, P, P′, alternately up and . These levers are connected by strings or wires heir respective heddles, which are in their turn in communication by straps which play over all rollers, *e*, *e* at the top of the loom.
ig. 105, the levers, P, P′, have been shown in in order to explain the way in which the ec-s, tappets, or cams, work through the interven- two small friction-rollers, made fast to the

shuttle is thrown by the two levers, Q, Q, which ternately moved with a jerk by the rollers, R, by arms on the shaft, E, and working upon cams nected with the shafts of the arms, Q, Q. These which represent the right arm of the hand-weaver, are united by the pecking-cord, T, which unted with a spring of spiral wire, so that either may be brought to its proper relative position.
e shuttle is lodged in one of the boxes, *f*, *f*, of the n, H, and is driven across along its shed-way by of the pickers, *g*, *g*, which run on the two parallel e-wires, *h*, *h*, and are connected with the peg-s, Q, by strong cords. *See* fig. 105.
f by any accident the shuttle should stick in the d-way, the blows of the lay, or batten, H, against it, uld very soon cause the warp to be torn to pieces. order to guard against this misfortune a contrivance as been introduced for stopping the loom immedi-tely, in case the shuttle should not come home into ts cell. Under the batten H, fig. 106, there is a small shaft, *i*, figs. 104 and 106, on each side of which a lever, *l*, *l′*, fig. 104, is fixed. These two levers

are pressed by springs against other levers, *m*, *m*, which enter partly into the shuttle-boxes. They act there as brakes to soften the impulse of the shuttle, and allow, also, the point of the lever, *l*, to fall downwards into a line with the prominence at *n*, provided the shuttles do not enter in and press the spring-point, *m*, backwards, and

Fig. [illegible].—Sharp and Roberts' Power-Loom. Second side elevation.
Scale, one inch to the foot.

thereby the upright arm of the bent lever, l', onwards, so as to raise its horizontal arm, l, above n. When this does not take place, that is, when the shuttle has not gone fairly home, the lever, l, hangs down, strikes against the obstacle n, moves this piece forwards, so as to press against the spring lever or trigger o, o, which leaps from its catch or detent, shifts the fork, p, p, with its strap, from the fast to the loose pulley at B, fig. 105, and thus in a twinkling, arrests every motion of the machine. *See* figs. 104 and 105 at the right-hand sides.

The shuttle is represented (fig. 107) in a top view, and fig. 108 in a side view. It is made of a piece of box wood, excavated by a mortise in the middle, and tapered off at its ends, the tips being shod with iron-points to protect them from injury by blows against the guides and the bottoms of the boxes.

In the hollow part, a, b, there is a skewer or spindle, c, seen in dotted lines. One end of this skewer turns round about the axis, d, to allow it to come out of the mortise when the cop is to be put on.

e (see the dotted lines in fig. 108) is the spring which keeps the spindle, c, in its place by pressing against one of the sides of the square ends of the spindle. f is a projecting pin, or little stud, agains which the spindle, c, bears, when laid in its place. g is a hole in one side of the shuttle, bushed with ivory, through which the thread passes, after being drawn through a slit in the centre of a brass plate, h. In that side of the shuttle which is furnished with the eye-hole, there is a groove extending its whole length for receiving the thread in its unwinding from the cop. The under surface of the shuttle, which slides over the

warp-shed, is made smooth from end to end by means of two wires, which abate the friction.

Thus we see that in the power-loom, there are eight points to be considered :—

1. The framework of the machine.

2. The mechanism connected with the warp.

3. The movement of the healds or heddles.

4. The movement of the lathe or batten.

5. The movement of the shuttle.

6. The mechanical arrangements of the whole machine.

7. The mode of action, or working of the several parts.

8. The methods of throwing the loom out of geer.

1. The *frame-work* is of cast iron, and is composed of two sides, each being cast in a single piece marked A in the three figures, in which are seen an upright at each

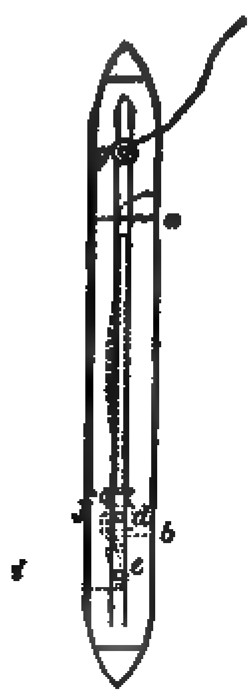


Fig. 107. Fig. 108.
Sharp and Roberts' Power-Loom Shuttle. Scale, two inches to the foot.

end, a cross-bar at top and bottom, with a curved bar diagonally placed. Upon the front of the uprights in fig. 105, immediately above the letter A, there are notched brackets for supporting the iron axes of the cloth-beam, N. On the back uprights of the loom, there is a slot-bar for supporting the axes of the warp-beam, I, see fig. 104. Towards the middle of the top rails of each side the vertical prolongation terminates in the arch A′.

The cross binding rails which unite the two faces and the two ends of the loom are,—

1. The great arched rail, A′, fig. 105, shaped like a basket-handle, which is made fast by screw-bolts and nuts, of which the heads are seen under A′ in fig. 104. This arc is destined to support the heddles, *e*, *e*.

2. The front cross-rail, A′, fig. 105, bifurcated at the ends to afford a greater extent of binding surface with the uprights.

3. The back cross-rail (not seen in these views), perfectly similar to the front one, A′.

The frame-work is exceedingly substantial, and stands steadily upon four large feet. The floor which bears it should be free from tremor, a stone or brick floor, on the ground story, being the best.

2. *Arrangement of the Warp.*

The warp is wound, as we have said, upon the cylindric wooden beam, I, figs. 104 and 106, from which it passes over the guide-friction roller, K, whereby it is brought into a horizontal plane suited to the play of the shuttle and the lathe. The cloth being formed at *r*, figs. 104 and 106, progressively slides over the strong breast-beam, M, and is wound upon the cloth-beam, N.

It is essential to good work in the power-loom, that the warp and the cloth be uniformly stretched to the proper tension during the whole process of weaving; for if it become at any time greater, more force will be required to move the heddles in opening the shed, the yarns will get broken, and one shoot cannot be driven so close home upon another as when the tension is less. On the other hand, if the web be left too slack, the shoot of weft will be driven too far into the shed, and will thereby ride, in some measure, over the warp. It would not be difficult to give the chain the requisite degree of tension for the particular style of goods, were it not necessary to maintain it at the same pitch all the time that the cloth is winding, and the warp unwinding about their respective rollers. The warp-beam, I, has, at each of its ends, a large wooden pulley (one is seen in fig. 104,) which are fixed by screws upon the disc iron plate; round that pulley a cord makes two or more turns, and then hangs down with the tension weight at its end (see fig. 104); a lighter counter-weight, not seen in this view, hangs interiorly from the other end of the cord. The weight, *s*, consists of round plates of cast-iron, and it may, therefore, be modified at pleasure by increasing or diminishing their number.

The roller, K, may be raised or lowered upon its rack-work upright, as shown in fig. 104.

The surface of the breast-beam, M, slopes slightly, and is made very smooth to facilitate the sliding motion of the cloth in its way to be wound upon N.

The cloth-roller, N, bears upon one of its iron axes prolonged the toothed wheel, *a*, which works into a pinion (seen in dotted lines, *u*, in fig. 104,) upon the

axis of the ratchet-wheel, *b*. Hence if the ratchet-wheel be turned round, it will turn the pinion, *u*, and the wheel, *a*, on the shaft of the cylinder, N, so as to wind up the cloth as it is made. The click-lever on the top of the ratchet-wheel makes it hold whatever it has got, and thereby prevents the cloth from unrolling.

3. *Movement of the Heddles.*

These are of the usual construction in this power-loom; they are shown in section at L, L′, fig. 106, and in front view in fig. 105. The loops or eyes, *v*, fig. 106, through which one-half of the threads of the warp passes, lie in two ranges; as also the loops, *v′*, of the other heddles, which transmit the other half of the threads. The loops are arranged in two ranks, and in different planes (on different levels,) in order that the warp-yarns in passing may be brought closer together. Thus the even numbers of threads, 2, 6, 10, &c., which belong to the heddle, L, pass in the loops of the first or upper range, and the numbers, 4, 8, 12, &c., in those of the second range; and the odd numbers of threads, 1, 5, 9, &c., which belong to treadle, L′, pass in those of its upper range, and the numbers, 3, 7, 11, &c., in those of the second.

With the same view there are two heddle-sticks at L, L′, so that the threads which belong to the first range of loops may be received over the two front rods above and below, and the threads which belong to the second range may be received over the two back rods. In fig. 106 the line of division is shown in the middle of the section of the heddle-rods at L. The same takes place with the other heddle, L′.

The rods of the first heddle-leaf are each attached

above to two cords terminating in leather straps, *e, e,* (fig. 105) the ends of which are nailed to the wooden pulleys, as shown in section at *e*, figs. 104 and 106. The rods of the second heddle-leaf are in like manner attached by two cords, with two leather straps nailed to similar pulleys. The last two pulleys have a smaller diameter than the first. Both systems of pulleys are fixed upon an iron shaft, which turns in the notch-bearings of the bracket projecting from the point, A′, of the basket-handle rail (as shown at *e*, fig. 104).

At their under part, the heddle-leaves are also attached by two cords to two strong wooden bars, U, V, to the middle of which are fixed the iron rods, O, O, which are jointed to the treadle-marches, or steps, P, P′. These are connected by screw-joints (fig. 105), so that the point of attachment may be varied according to circumstances.

We must now show how the treadles or marches, P, P, (figs. 104 and 106) are raised and lowered, and how they effect, at the same time, the elevation and depression of the heddles

In figs. 104 and 106 are seen the two bent lever-bars, P, P′, which turn upon a fulcrum at W, and which are prevented from deviating sidewise by the upright fixed bars, which pass through slits in their middle, as shown in fig. 106. When the march or lever, P, is pushed down, depressing the front heddles, the lever, P′, necessarily rises, because the one leather strap cannot roll round the pulley, *e*, without unrolling the other, and reciprocally. In order to shed the warp alternately, first in one direction and then in another, nothing is required but to depress, in succession, each

of the treadles or levers, P, P′, taking care not to obstruct the motion of the rising one.

The movements, 4 of the batten, and 5 which throws the shuttle, are essentially a little complicated, not so much from any difficulty of giving them the requisite velocity, as from the necessity of making them start precisely at an instant, dependent not merely on the position of the heddles, but on that also of the batten.—*See* pages 302, 303.

6, 7. *The Communication of Motion, or the Train of the Working Parts.*

The driving-shaft, which puts the whole machine in motion, is represented by B, figs. 104 and 106. It is supported by the upper cross-rails, which extend beyond the side-frames, to carry upon the right hand the toothed wheel, D, fig. 106, and to the left the pulleys or outriggers, C, fig. 104, upon which the steam-belt runs. Inside of the frame, opposite each of the swords, G, of the batten, there is a crank mechanism, B, F, upon the driving-shaft, to which the links, F, *y*, are adjusted which move the batten. It is therefore evident that, for every turn of the fly-wheel, C, or the steam pulley-shaft, the batten must make a complete vibration to and fro, advancing each time so as to beat up the shoot of weft at exactly the same point. Hence if the main-shaft make 120 revolutions in the minute, the shuttle must pass 120 times along the shuttle-rail.

The toothed wheel, D, figs. 105 and 106, making as many turns as the fly-wheel, works in the toothed wheel, D′, of double diameter, and therefore communicates to it half its own velocity. This wheel, D′, is made

fast to one of the extremities of the tappet, or wiper-shaft, E, (figs. 104, 105, and 106,) whose two bearings are in the curved diagonal rails, X, fig. 104. This shaft, E, is moreover supported in the middle by a clamp-collar, between O and O, fig. 105, in order to guard it against the least flexure, in consequence of the heavy strains it is exposed to in moving the treadles.

The eccentrics, O, O′, are mounted upon the shaft, E, and turning with it, impart alternate pressure to the marches or treadles, P, P, as well as to the pecking arms, Q, Q′. The effect of these eccentrics may be readily conceived from their being of a spiral form, but with their curves placed in opposite positions. Hence if from the common centre of the two eccentrics any radius be drawn to the two circumferences, the sum of the two portions of it, intercepted by the centre and each circumference will be a constant quantity, which is the essential condition to be fulfilled by these eccentrics, to give equal alternate impulsions.

The ratio between the greater and smaller curvature of these eccentrics, depends upon the extent of the opening or shedding of the warp, for the shuttle-race. In the figures here engraved, the measurements are ¼ and ½ inch, which, by the scale of 1 inch to the foot, gives 3 inches and 6 inches; and as the bottoms of the upright rods, which move the heddles, work in the levers, P, at a distance from the fulcrum, W, one-half greater than the eccentrics, O, or as the fraction $\frac{3}{2}$; the movement of the heddles will be $\frac{3}{2} \times 3$ inches $= 4\frac{1}{2}$ inches. In order to open the shed still more, the lower ends of the heddle-rods would need merely to be removed by the slots and nuts farther from the fulcrum, W, that is, nearer to the

points of the treadles, or tappet-wheels, O, O, of a greater eccentricity may be used.

It is obvious that there should be a certain relation between the position of the crank elbows, B, F, figs. 104, 106, and the position of the eccentrics, O. Thus, in figs. 104 and 105, the main-shaft must make one-quarter of a turn before the crank, F, with its link, F y, can strike the batten, H, against the shoot of weft. During this quarter of a turn, the tappet shaft, E, moving with one-half the speed, will make only one-eighth of a turn. The position of the eccentrics must be nicely adjusted upon their shaft, to that of the crank, and firmly fixed in that position, so that the batten may strike home the shoot upon the closed warp, or upon the warp still partly shed, as may be thought preferable. In the position shown by the figures, the lay will strike somewhat before the closing of the shed; for the eccentric or tappet-shaft, E, will make one-eighth of a turn, equivalent to one-quarter of a heddle-stroke, while the crank-shaft, B, will make the quarter of a revolution requisite to drive home the lay upon the shoot.

We may now readily apprehend in what manner the double arm throws the shuttle at the proper moment. The two levers, (figs. 104 and 105), which produce the pecking motion, are actuated by two friction-rollers, (one of which is seen to the right of R, fig. 104,) attached to the eccentrics or tappets, and diametrically opposite the one to the other. By shifting the position of these projecting rollers in the curved slot of the eccentric, R, the throwing of the shuttle, effected by their striking down the pecking

lever, may be adjusted to any point in the revolution of the tappet-shaft, which moves the heddles. As the shuttle can be thrown, however, only when the warp is open in a considerable degree, the screw-bolts which carry the wiper-rollers cannot be moved beyond the space included within the extremities of the great arcs of the eccentrics. And since there are two rollers diametrically opposite, it is obvious that in each complete revolution of the eccentrics, the shuttle must be thrown twice; and as each of these revolutions corresponds to two revolutions of the crank-shaft, or two strokes of the batten, there will result, as there ought to do, one stroke of the battens for every passage of the shuttle.—For point 8, *see* page 295.

I have seen this power-loom weaving at very various speeds, from one hundred pecks or shoots in the minute, up to one hundred and eighty. The average number in the most improved loom-shops for weaving calico, may be reckoned one hundred and twenty.

Near to each of its ends the warp-beam has two square-grooved large wooden pulleys, which are fixed by screws upon the cast-iron discs. These discs have a hollow socket in their centres for receiving the ends of the beam; and they also are fixed by four screws, which pass down through this socket into the wood. To give them a firmer hold, the sockets have a projecting feather or wedge within, which fits into a square groove or mortise cut in the side of the roller. Round the smaller pulley a cord makes two turns, carrying upon its inner extremity a light weight and upon its outer one a much heavier weight. Round the larger pulley, at the other end of the warp-beam,

a similar tension cord passes, but it makes four turns, bearing analogous weights to the former pulley. One of these weights is seen at *s*, figs. 104, 106.

When the warp has been made fast, by securing its ends in the longitudinal groove of the beam and by forcing the wedge-rule down upon the threads, and when it has been led over the guide-roller, K, and the breast-beam, M, and is tied in several little parcels to the cloth-beam, N, held by its ratchet-wheel, it will be stretched to a degree determined by the difference of the above pulley-weights.

Let us recapitulate the train of its decussating operations beginning at the moment when the shed is closed, that is, when the two heddle-leaves are at the same level, as well as the tappets of the treadles, which are now pressed by the intersecting points of the tappet-wheels. The batten is likewise at the limit of its advance, in the direction of the cloth, namely, striking home the shoot of weft. Supposing the loom to make 120 pecks in the minute, it will make, of course, a single peck in half a second; hence the fly-shaft makes a turn in half a second, and the tappet or eccentric-shaft makes a turn in a whole second. In moving from the above position the tappet-wheels must make $\frac{1}{12}$ of a revolution in order to open the warp-shed completely, during which movement $\frac{1}{12}$ of a second will elapse: it remains open $\frac{4}{12}$ of a second, and takes again $\frac{1}{12}$ of a second to close, so that $\frac{6}{12}$, or one-half of a second, elapse between the moment when the warp begins to open, and the moment of its closing, while it remains completely open $\frac{4}{12}$ of a second.

The shuttle is thrown at the moment when the

tappet-roller at R, strikes the bent lever P beneath it, but the warp must not be merely opened for the shuttle to be thrown; the batten must be then at its utmost limit towards the heddles, in order to give the shuttle "ample room and verge enough." This is the condition which determines the place of the tappet-rollers upon the eccentrics. As the batten arrives near the heddles after $\frac{3}{16}$ of a second, it is obvious that the said roller should strike its lever a little before $\frac{3}{16}$ of a second have elapsed, or a little before the middle of the great arc of the eccentric; thus the shuttle starts before the batten has receded to its utmost limit towards the heddles, and it should have run through a little more than one-half of its race when the batten reaches that limit, so that it may arrive in time at the other end.

When the shuttle completes its race, the batten has already passed the limit of its excursion towards the heddles, and is on its return to strike home the shoot of weft newly placed between the two portions of the opened warp. It has now its maximum velocity, because the cranks, B, F, are at nearly right angles to the links which move the swords, G, of the battens. This velocity diminishes in order that when the dents of the reed, borne along by the lay, come into contact with the weft to drive it home, they may act by gentle pressure rather than by a blow, so as not to injure the yarn. The warp being closed at the same instant, the pressure does not affect the loops of the heddles, but is exercised upon the warp and the cloth, wholly in a longitudinal direction.

Mr. Roberts obtained a patent, so long ago as November, 1822, for a power-loom having six heddles, adapted to weave twilled cloths or fustians, and such

other fabrics as have the threads crossed in weaving, in that peculiar manner called twill. In this case, the tappet-wheel is formed of two equal parallel rims, a few inches apart, which carry between them nine small axles; on each of these axles are six small friction-rollers, making, in the whole, fifty-four friction-rollers. These rollers are intended to act upon twelve curved lever-treadles (such as P, P, in the immediately preceding description). This tappet-wheel, by its revolution, causes the said friction-rollers to strike alternately upon one or other of the treadle-levers, and to force them down, by which means the respective heddles are depressed and raised at certain parts of the operation, so as to draw the sheds of the warp up or down to permit the shuttle to pass, and to dispose the warp according to that particular arrangement which is calculated to produce a twilled fabric. In order to vary the twill the friction-rollers are capable of being shifted, and, by so disposing the collets between the rollers, certain of them may be placed so as not to act upon one or more of the treadle-levers. The other arrangements of this twill-loom resemble those of the plain-work loom above described.

The second improvement specified by Mr. Roberts under that patent, applies to that description of loom employed for the weaving of figured goods, and consists in certain machinery to be placed above the loom, for the purpose of effecting the raising and depressing of such parts of the warp as are usually operated upon by the draw-boy. There is very considerable difficulty and labour in setting-in any particular pattern, figure, or design by the old mode, but they are in a

great measure avoided by the plan proposed under the present patent.

Mr. Robert Bowman, of Manchester, had, in January, 1821, obtained a patent for an ingenious power-loom calculated to perform several of the functions assigned to that of Mr. Roberts. The patentee observes, that the manner in which power-looms had been hitherto constructed did not admit of employing so many heddles as were requisite for weaving those kinds of fabrics called *fustians*,—such as velvets, velveteens, corduroys, &c., which are of the nature of twilled or tufted cloths. He describes his present improvements as consisting of such simple modes of harnessing the heddles of power-looms, and of applying the tappets or wipers to draw down the heddles, that he is enabled to manufacture the before-described cloths by power-looms, with the same facility and perfection that they could be produced by hand-weaving.

The heddles (six in number) in Mr. Bowman's loom are suspended by cords which proceed from the extremities of levers at the top of the machine, and are also attached to another set of levers, or treadles, at its bottom. The moving mechanism is exterior to the cheeks of the loom, at the left-hand side. The outer ends of these levers are connected by cords or rods which brace the heddles to any required tension, and, being equipoised, are free either to rise or fall without causing any unnecessary strain upon the warp. The movement for raising and lowering the heddles is obtained by means of two sets of tappet-wheels, or rosets, as many in each set as there are heddles, which tappet-wheels are fixed upon two axles,—one above,

the other below, the main axle of the machine. The tappet-wheels or eccentrics are turned by means of a pinion upon the end of the main or crank-shaft, which takes into the toothed wheels upon their axles, and each of the tappet-wheels is designed to make one revolution for nine shoots of the shuttle.

In other respects this power-loom does not differ in principle from the one we have described in detail. It differs from Mr. Roberts's fustian-loom, in having several tappet-wheels instead of one compound wheel, mounted with fifty-four friction-rollers, and in having its lever machinery on the outside of the end frame of the loom. Both are calculated to make good work, and well merit their respective shares of public approbation.

Mr. William Horrocks, formerly of Stockport, afterwards of Portwood, in Cheshire, of whose improvements mention has been made, obtained a patent in December, 1821, for an invention which consisted in adapting an apparatus to it for the purpose of wetting the warp and weft at stated intervals during the process of weaving. He placed an oblong trough, containing water, or a solution of soap and water, across the loom under the warp, which he applied by a rod or bar covered with cloth, which was made, by two short arms, alternately to descend into the trough and rise up to the under side of the warp, thereby conveying a small quantity of the liquid both to the warp and weft, so as to moisten them, and thereby enable the weaver to compress in the fabric any quantity of weft that may be required.

I have not seen this scheme employed in any of the numerous power-loom shops which I visited. It is probable that the improved modes of dressing the

warp and preparing the weft-cops, have rendered the ingenious appendage of Mr. Horrocks superfluous.

A patent was granted, in October, 1823, to Archibald Buchanan, Esq., of the Catrine Cotton Works, Ayrshire, for an improved power-loom, to produce a variable speed in the vibration of the lay or batten, so that the lay may be as nearly stationary as possible at the time the shuttle is passing through, while it may move with a rapid smart stroke when beating up the web. This invention was therefore confined to that part of the machinery which actuates the lay, and consists in the adaptation of two eccentric toothed wheels to it. This adjustment exists in Roberts' loom.

It is stated by the patentee that, in a loom so modified, he can project the shuttle across a web of a yard wide, at the rate of 130 times per minute, without producing more breaking of the threads than usually occurs in looms driven at the rate of 80 or 90 shoots per minute.

I have seen this loom doing good work at the above speed in Scotland; but whether from the increased complexity of its construction, or whether from the improved mode of adjusting the crank-lever mechanism above described, Mr. Buchanan's loom has never come into general use in the Lancashire district. His specification is written in a clear philosophical style, characteristic of his known scientific attainments.

Messrs. Stansfield, Briggs, Prichard, and Barraclough, of Leeds, or its vicinity, obtained a patent in July, 1823, for three improvements upon power-looms: the first two being peculiar modes of delivering the warp as it is needed, and the third a method of increasing and diminishing the tension of the warp, at

intervals, for the purpose of assisting the operation of weaving.

According to one of the plans, the warp is delivered by means of a ratchet-wheel made fast to the end of its beam, which is drawn round by a pall or catch-arm, as described for turning the cloth-beam of Sharp and Roberts' loom, with an adjustment, by the pressure of a lever, for equating the speed of rotation to the diminishing diameter of the beam, as its warp is unwound.

The third improvement is a mode of varying the tension of the warp-threads, so as to relax them when the sheds are opening, and to draw them tight when the batten advances to beat up the weft. There are two small rollers extending across the back of the loom,—one immediately below the warp, the other above it: the former is pressed up against the threads by a small wire spring. By a cam, or heart-wheel and levers, the upper roller is made to press down upon the warp and tighten the yarns, and to rise up and leave them slack alternately.

This ingenious device seems well adapted to the very extensile filaments of wool, or delicate silk threads; but it has not, as far as I know, gained a footing in the cotton-factory loom-shops.

In June, 1824, Mr. William Harwood Horrocks, of Stockport, obtained a patent for a newly invented apparatus for giving tension to the warp in looms; consisting in a method of restraining the delivery of the warp by the friction of a hoop which embraces a wheel at the end of the beam. This hoop is formed of two semicircular bars of iron, which are made to embrace a pulley upon the end of the warp-beam, with

greater or less force, by means of screw-bolts passing through the junction-ends of the two half-hoops.

Mr. Joseph Clissold Daniel, of Stoke, Wilts, patented, in July, 1824, a power-loom for weaving woollen cloth, which, on account of its ingenious modification, merits a brief notice here. The novel features are threefold :—1. The introduction of a spring behind the lay or batten to which the crank-rod is attached, that causes the lay to vibrate; 2. The employment of a weighted lever, which tumbles to and fro on the treadle-shaft, for the purpose of throwing the warp open to receive the shuttle; and, 3. The introduction of oblique brushes, or card-rollers, in the breast-beam, in order to stretch the cloth out towards the sides, and prevent its wrinkling in the work-beam as it rolls up.

Certain contrivances adapted to a power-loom, by which the warp-threads are given out from the beam, and the cloth taken up by the work-roll in a more advantageous manner than has heretofore been effected, were made the subject of a patent granted to Mr. Thomas Woolrich Stansfield, of Leeds, in July, 1824. The warp-threads are here made to pass *downwards* from their beam over two tension-rods at the back of the loom, and then up over the usual guide-roller which lies on a line with the shuttle-race and breast-beam. There is a lever attached to the undermost tension-rod, which starts each time that the lay strikes the weft, by the twitch thereby given to the warp, and which withdraws for a moment the detent at the reverse end from the ratchet-wheel attached to the warp-beam, by which means one tooth escapes, and allows an adequate supply of warp to be delivered. There

are other ingenious devices in this machine, for which we must refer to the specification. The second subject of this patent is a mode of putting a series of looms to work by one rotatory shaft, and of stopping the action of any one of these looms without interfering with the other looms connected with the same shaft.

John Potter, Esq., of Smedley, near Manchester, obtained a patent in May, 1825, for the "invention of certain improvements in power-looms for weaving various kinds of figured fabrics." A series of heddles are mounted upon cords connected with a series of top and bottom levers attached to the loom; and as these levers rise and fall, the heddles, with certain of the warp-yarns connected with them, move up and down also, between every throw of the shuttle. The contrivance by which the levers are to be moved is very similar, in one part, to the mechanism of a barrel-organ, and in another to the principle of the Jacquard loom.

The third subject is a mode of preparing warps upon a plan analogous to that already explained in describing Lillie's sizing machine.

A patent was granted in the same year to Mr. Spilsbury, of Leek, for a power-loom for weaving figured goods, which had for its object a simple and economical method of reading in, and weaving an elaborate pattern. The improvements may be referred to two heads; 1, to the means proposed in place of a draw-boy, for raising the various parts of the warp, so as to produce any required pattern; and 2, to the mechanism for working the different evolutions of the loom. This improved mechanism was primarily intended for

weaving silk, and has not, as far as I know, been hitherto introduced into the cotton trade.

Mr. John Harvey Sadler, of Hoxton, near London, obtained a patent in May, 1825, for an improved power-loom, in which motion was given to the working parts by means of a rotatory power, so applied that its mechanism should occupy no greater space than is required for the standing of an ordinary hand-loom. On measuring the dimensions of Sharp and Roberts' power-looms by the scale of the figures given in this work, it will be found to occupy much less space than most hand-looms.

The improvement in the power-loom for weaving tapes, for which Messrs. Worthington and Mulliner, of Manchester, obtained a patent in June, 1825, would merit a detailed notice, from its practical utility, did the small-ware manufacture fall within the scope of the present work. It is a very ingenious modification of the power-loom above described, and is now working in a most satisfactory manner, in Messrs. Worthington's excellent factory.

An improved method of making heddles, by Mr. John Rothwell, of Manchester, became the subject of a patent in January, 1826. He proposed to make the loops of the heddles double, that is, passing over the shafts at the top and bottom, and meeting both at the back and front; and also that they should be formed of long and short loops alternately. By these means the knots of the one series of loops will be a little distance above the knots of the other series of loops; and the warp-threads will be enabled to pass each other with greater freedom, and of course with less friction;

the space for the warp being open in the middle. Heddles are usually made of fine woollen or hempen cords, twisted very hard, and sold under the name of heald, or heddle-yarn. Heddles have also been made of wires.

A curious contrivance of Messrs. Stansfield, Pritchard, and Wilkinson, of Leeds, was secured by patent in July, 1825. It consists, first, in a small appendage to the shuttle, by which, in the event of the *weft* thread breaking, the shuttle is arrested in its race, and the actions of the loom stopped; secondly, in an apparatus attached to the back of the lay, for the purpose also of stopping the shuttle when any of the *warp* threads break. I am not aware that these refinements have been brought into play in any of the great power-loom factories about Manchester. They merit attention, and will no doubt be eventually adopted, with more or less modification.

The patent granted to Mr. George Scholefield, in March, 1828, for certain mechanical contrivances, which connect all the operating parts of a common loom together, and cause them to act simultaneously whenever motion is given to the loom, seems to be important; as the machine will enable any person, without previous experience or knowledge of the art, to weave cloths with facility. The plan has been hitherto, I believe, restricted to the weaving of woollen goods.

It is difficult, in perusing the specification of a patent, to determine the value of the invention, which depends often upon some apparently insignificant circumstance.

This remark may be justly prefixed to the following notice of the power-loom of Mr. John Paterson Reid, for weaving lappets, and figured muslins in general.

He obtained a patent for his improvement in April, 1827, and he has since proved its value by the superior quality and economy of his manufacture of the above styles of goods.

The batten, or lay, in his looms, does not vibrate upon centres, as usual, but slides to and fro in a horizontal direction, by means of guide-rods, which pass between guide-rollers. The batten is actuated by an arm connected with an eccentric wheel at the one end, and with a spring fixed to the under side of the batten at the other. This eccentric wheel turns upon an axle, and, as it revolves, its circumference acts against a friction-roller at the end of the batten, contrived for the purpose of guiding the batten steadily, as it advances and retires.

When the smaller radius of the tappet, or eccentric wheel, is in contact with the said roller, the batten is brought back, which is the time of the shuttle's being projected across, between the sheds of the warp; the wheel is therefore made with this part of its circumference nearly concentric, so that it may continue to turn round without advancing the batten, until the shuttle has got clearly through the warp, and been lodged in its box at the end of its race. The opposite radius of the eccentric wheel is large, in order to push forward the batten with the requisite force, for beating up the weft. But as some degree of elasticity is necessary in beating up the weft, to prevent the delicate threads from breaking, the rod is attached to a spring, which allows the batten to recede a little when driven up with force; thus imitating the tact of the weaver's arms. The spring may be made in any way that shall be found eligible, and it may be rendered susceptible

of greater or less tension by methods indicated by the patentee.

Mr. Thomas Robinson Williams, under a patent obtained in February, 1830, proposes to substitute, for the warping-mill, a creel, containing a series of bobbins connected with the warp-beam end of the loom, whose threads are passed round two different friction-rollers before they proceed in the horizontal warp-plane, towards the heddles. Such a loom would be so cumbersome and inconvenient to work, as to be disadvantageous in practice.

An invention for stopping the loom when a weft-yarn breaks, was made the subject of a patent, by Mr. Archibald Douglas, of Manchester, in April, 1833. He included, also, in the same specification an apparatus to be connected with the batten, by means of which the action of springs attached to it is regulated, and adapted to the production of different figures, as a solid stripe or cord across the work; and likewise an improved apparatus for regulating the taking up motions of a loom, and the number of pricks in an inch. The apparatus seems to be ingenious, but is too complex to be understood without numerous figures of reference, for which we cannot afford space in the present work. Should it become an integral part of our cotton manufacture, a detailed account of it may be introduced on a future occasion.

A more immediately applicable improvement upon power-looms, is that of the self-acting temple, or templet, for which William Graham, Esq., of Glasgow, obtained a patent in May, 1833.

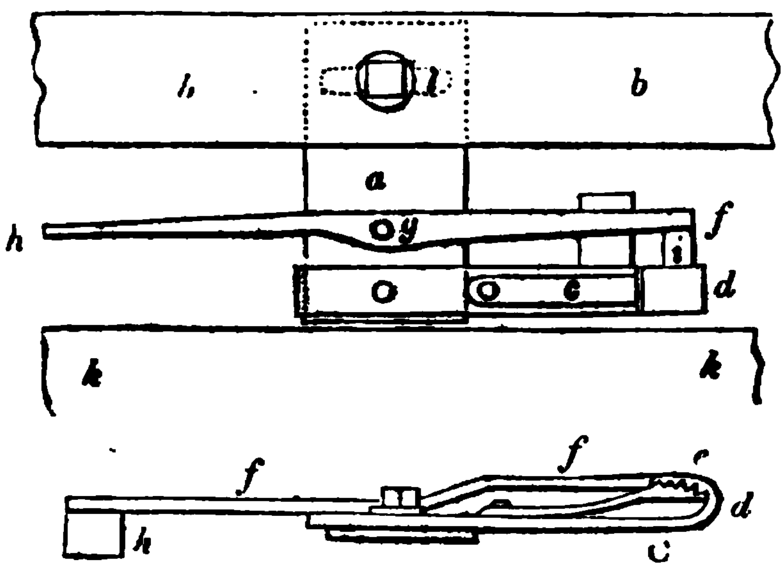
We have already explained that the temple is an apparatus to be attached to looms for the purpose of

keeping the cloth, as it is woven, distended to its full width, and thereby preventing the warp from being abraded against the dents of the reed, which would happen, were the cloth allowed to shrink into a narrower breadth than the sheet of warp.

In hand-looms the temples are formed by two stretcher-pieces of hard wood, connected together in a nearly parallel direction by cords, and laid across the web; the ends of these stretchers being studded with pin-points, which penetrate the list or selvage upon either side, and thereby keep the cloth extended.

In power-looms, for want of a self-acting temple, each loom must be constantly watched by an operative. To obviate this expense and inconvenience, several plans have been devised; such as revolving stars placed in such positions as should cause the points to take into the lists of the cloth. None of these schemes have been found to answer so well as the American *nipper-temples,* which form the subject of the present patent.

Fig. 108 is a horizontal view of one of the nipper-temples, and fig. 109 is a vertical section of the same.



Figs. 109 and 110.—American Nipper-Temples.

One of these nippers is to be fixed near each end of the breast-beam, where it is acted upon by the swinging of the lathe, or batten, which opens the chaps of the nippers at every operation of beating up, and thereby releases the cloth, and allows it to be slidden forward, over the breast-beam.

The plate, *a*, to which the nippers are attached, is to be fixed to the breast-beam of the loom, *b*, *b*, by means of a screw-bolt passed through the said beam, as shown in the figure. When different widths of fabric are required to be woven, the temples must be shifted nearer to, or further from, the *ends* of the breast-beam, which may be done by means of a long slot, *l*, shown by dotted lines in fig. 108.

Towards the outer end of the plate, *a*, a bar, *c*, is attached, which is turned up at the end, and bent back to form the upper chap, *d*, of the nippers. The lower chap, *e*, fig. 109, forms part of a spring-piece affixed to the bar, *c*, and is pressed up by its spring against the upper chap, *d*; the inner surfaces being channelled like a file, to enable them to hold fast. Between these two chaps the list of the cloth is passed, and being thus held by the nippers upon each side of the loom, the cloth is kept stretched to its proper width.

A horizontal lever, *f*, *f*, fig. 109, turns upon a fulcrum-pin, *g*, fixed in the plate, *a*; and at one end of this lever there is a broad piece, *h*, hanging down, and at the other end a knife-edged tooth, *i*, projecting.

The under part of the front of the batten is partially represented at *k*, *k*, which, when it goes forward to beat up the work, strikes against the end, *h*, of the lever, *f*, and causes the knife-edged tooth, *i*, at the

reverse end to be forced in between the chaps, *d*, *e*; which merely opens the chaps, and releases the cloth at the moment that the weft is beaten up, thus allowing the reed to drive the work forward, over the work-beam as usual. But the instant that the batten retires, the tooth, *i*, slips back out of the chaps of the temple, and the cloth is held tight, as before.

In this way the nippers act at every stroke of the batten, opening, so as to release the cloth, and closing again to keep it at a tension, constituting self-acting, or perpetual temples.

In July, 1834, Messrs. John Ramsbottom and Richard Holl, of Todmorden, Lancashire, obtained a patent for certain improvements in the construction of power-looms; consisting, 1, in a peculiar arrangement by which two pieces of fabric may be woven at one time through the agency of a rotatory axle; 2, a contrivance for instantly stopping the working parts whenever the weft-thread breaks; and 3, an apparatus of self-acting temples.

In this improved loom, the warp-threads are placed vertically in two ranges; the one range extending from a roller below, towards a work-beam at top in front of the loom; the other range extending similarly at the back of the loom; and the double batten or lathe, in which the reeds are mounted, instead of making pendulous movements, as in common looms, rises and falls in vertical planes, while the heddles are moved to and fro in horizontal planes by means of a vibrating lever.

The contrivance for stopping the loom on the breaking of a weft-thread is very ingenious. It consists of levers, called by the patentees hands with fingers, attached to rods extending across the loom, and turn-

ing in bearings upon the side standards. At each end of the reed there is an aperture in the shuttle race, covered by a grating of parallel slender iron wires, set sufficiently apart to allow the vertical wire-fingers (like a many-pronged fork) of the mechanical hand, to fall through when no obstacle intervenes. When the weft-thread is entire, it is stretched across the surface of that parallel wire grating, and sustains the weight of the tiny fingers; but if it is broken, the fingers will fall through into the entrance of the shuttle-box. In the latter case, the rod across the loom is turned, and a lever attached to it presents a catch to a transverse bar projecting from the end of the lathe, whereby a trigger is let off, which shifts the driving band from the fast to the loose pulley upon the main shaft of the loom.

The above double loom is remarkably compact, occupying, apparently, much less space than a single power-loom of Messrs. Sharp and Roberts' construction. Whether it will be equally convenient and durable in working, must be determined by experience. Its arrangements are, in many respects, novel, and are highly creditable to the mechanical knowledge and skill of its inventors. The temples operate in a similar manner to the American, above described.

The latest of the improvements proposed upon the power-loom which we shall notice is that patented by Mr. Amassa Stone, of Rhode Island, in the United States, now resident in Liverpool, in October, 1834. It consists in a new adaptation of mechanism for the purpose of connecting the operation of beating up the weft-thread, with that of giving out or delivering the warp, and taking up the cloth; whereby, when from the breaking of the weft, the striking up of the reed

meets with little or no resistance, the delivery of the warp, and also the taking up of the cloth is suspended, although the general evolutions of the loom continue.

After every flight of the shuttle through the open shed of the warp, the lathe advances toward the work-beam for the purpose of causing the reed to beat up the weft-thread; but as the reed is here mounted in the lathe within a vibrating frame pressed forward by springs, the force with which it strikes against the cloth causes a rail parallel to the reed on which its lower edge rests, to recede or spring back from the lathe a short distance.

There is a perpendicular lever bearing at its top against the said lower rail. Whenever the reed-frame recedes, that end of the lever is necessarily forced back, and its lower end advanced, so as to push forward a horizontal rod attached to it. This movement of the horizontal rod near the floor causes the end of a bent arm to be brought close against the vibrating leg or sword of the lathe, and to draw back a click or pall over one tooth in a ratchet-wheel. On the return of the lathe into its original inclined position, the sword will strike against the end of the above bent arm, and cause the click (by a sliding rod) to drive the ratchet-wheel one tooth, and thereby turn a shaft with an endless screw, so as to turn round the warp-beam and deliver warp.

But if the weft-thread happen to break, there will be no delivery from the shuttle, and consequently a want of filling to the cloth; the reed, therefore, in beating-up will not meet with that resistance which it did when the fitting of the weft-thread was complete. Hence in the beating-up of the lathe, the reed-frame will not now re-

coil as before, nor will the upright lever attached to it be so acted upon as to cause it to shift the horizontal rod at its under end through the same distance; consequently, the pall or click will not be drawn over another tooth of the ratchet-wheel; and the shaft with the worm-screw will remain quiescent, leaving also the warp-beam at rest. An analogous effect is communicated to the cloth-beam.

This ingenious device seems well calculated to answer its end, and will probably be introduced ere long into power-loom factories.

A simple dandy-loom of Radcliffe's construction moved by power, making 84 pecks per inch, weaves 5 pieces of 30 yards each in five days.

Some of the coarse calico fabrics are very light. One great manufactory puts no more than 9 pounds in 36 yards; which is four ounces per yard.

A 72 reed at Stockport signifies seventy-two threads, or 36 dents, in the inch. When the piece is $\frac{7}{8}$ths broad in the dressing machine, there are 4 cylinders or yarn-beams at each of the ends. Each cylinder has 270 threads wound upon it at the warping-frame; hence $8 \times 270 = 2{,}160$, is the whole number of warp-threads in the breadth of the piece.

The 40's warps are woven commonly through a reed containing from 72 to 80 threads per inch, constituting in the language of Stockport, a 72 to 80 reed.

Mr. Orrell's looms made 92 picks per inch in a 72 Stockport reed, and 120 pecks per minute. I have seen a power-loom weaving very regularly under a good workman when making 180 pecks per minute. This was, however, merely for a short time to satisfy me that such velocity was practicable with Messrs.

Sharp and Roberts' loom. A manufacturer at Stockport informs me that he has brought up the speed of his power-looms, of that construction, to 130 pecks per minute upon an average. At this rate, a girl makes easily six pieces a week on each loom.

Book and jaconet muslins are now currently woven by power-looms, especially in the Glasgow district.

In Scotland, the number of dents or reed-splits in 37 inches, or the Scotch ell, constitutes the number of the reed; hence the above 80 Stockport reed, which contains 40 dents, corresponds to reed 1,480 in Scotland, as $37 \times 40 = 1,480$.

All cotton-cloth contracts about one-tenth of its breadth in weaving, in consequence of the contraction of the warp in the decussation of the weft-threads.

One reed-maker, with a boy, is capable of keeping 1,000 power-looms going in their business. The reeds contain from 900 to 1,500 dents each in their whole length, or from 48 to 80 per inch.

A cut of 60 yards will weigh in 27 inch-wide calico 13 lbs., consisting of Surats and Upland cotton wools.

Of Fustians.

The sets of reeds in which fustians, velveteens, and cords, are usually woven, are those of 32, 34, or 36 beers in 24½ inches, each beer containing 19 dents; so that $19 \times 34 = 646 =$ the number of dents, and the double of that number, or $1,292 =$ the number of warp-threads in the 24½ inches. Each warp-thread consists of good mule yarn, No. 32, doubled and twisted. The weft may be No. 24 mule yarn, and is single.

The ground or back of this style of goods is sometimes plain, or *tabby backed;* and sometimes tweeled,

or with a Genoa back. The flushing, or the part of the weft which is cut to form the lines of the velvet, or grooves of the cords, is thrown in and decussated with the ground at various intervals, whence the variety of the patterns is produced. We shall presently explain the art of cutting fustians, and of raising the pile, or forming the cut flushing into ridges above the parts of the weft which are embodied with the warp.

A much finer article of cotton velvet is prepared for ladies' mantles, of which the warp is 52's doubled, and weft 52's. The reed is one of 50 beers of 19 dents = 950 in 24½ inches.

In the plain-backed velvets there are two shots of the flushing thrown in for each shot of the ground. The term flushing signifies the several weft-threads which pass together over certain parts of the surface of the fabric without being decussated with the warp. Some flushed patterns are produced by extra warp or weft, either coarser than the ground, or of a different colour; others, and those the most common, proceed from certain portions of the weft which are floated above or below the warp.

A very luminous and instructive development of the principles of flushing every style of fancy texture is given by Mr. Murphy in his excellent 'Treatise on the Art of Weaving.'

The first process to which fustians are exposed after being woven is steeping in hot water to take out the dressing paste. They are then dried, reeled, and brushed by the machine described p. 328, fig. 111, &c. From twenty to thirty pieces, each eighty yards long, may be brushed in an hour. The breadth of the

cloth is twenty inches. The maceration is performed by immersing the bundled pieces in tanks of water heated by waste steam; and the washing by means of a reel kept revolving rapidly under the action of a stream of cold water for an hour or longer.

The cord has been previously cut by the knife, as described next page. After they are brushed in the machine, the goods are singed by passing their cut surface over a cylinder of iron laid in a horizontal direction, and kept red-hot by a flue. They are now brushed again by the machine, and once more passed over the singeing surface. The brushing and singeing are repeated a third, or even occasionally a fourth time, till the cord acquire a smooth polished appearance.

The goods are next steeped, washed, and bleached by immersion in solution of chloride of lime. They are then dyed by appropriate chemical means. After which they are padded (imbued by the padding machine of the calico printers) with a solution of glue, and passed over steam cylinders to stiffen them.

The knife used by hand for cutting fustians has the keel of its guard convex for cords, as it presses upon a tweeled fabric; but it is plane for velveteens where it runs over a single range of weft. Cords receive their last finish by being rubbed with an emery polisher, which is merely a bar of wood faced with coarse emery fixed by glue. Velveteens are finished by friction with bees' wax, and polishing with a wedge-shaped piece of hard wood.

Fustians have usually double yarns in the warp.

Apparatus for cutting the Pile or Cords of Fustians, Velveteens, Corduroys, etc.

Fig. 111 is a longitudinal section, and fig. 112 a cross section of the usual apparatus, as worked by hand.

Figs. 113 and 114 serve to explain the process which precedes the brushing.

After the cloth is taken from the loom-beam, it is carried to the cutter, who rips up the surface-threads of weft, and produces thereby a hairy-looking stuff.

Fig. 114 represents a section of fustian parallel to the weft. *b* the superficial weft-threads before they are cut; and *a* the same afterwards. Preparatory to its being cut, the cloth is spread evenly upon a table about six feet long, upon each end of which a roller mounted with a ratchet-wheel is fixed; the one to give off, and the other to wind up the piece, in the above six feet lengths.

The knife, fig. 113, is a steel rod about two feet long, and three-eighths of an inch square, having a square handle, *d*, at the one end; the other end, *c*, is tapered away to a blade, as thin as paper. To prevent this point from turning downwards and injuring the cloth, its under side is covered by the guide, *a*, which serves to stiffen it, as well as to prevent its lower edge from cutting the fustian.

The operative (male or female) grasps the handle, *d*, in the right hand, and insinuating the projecting point of the guide under the weft, pushes the knife smartly forward through the whole length of six feet, with a certain dexterous movement of the shoulder and right side, balancing the body, meanwhile, like

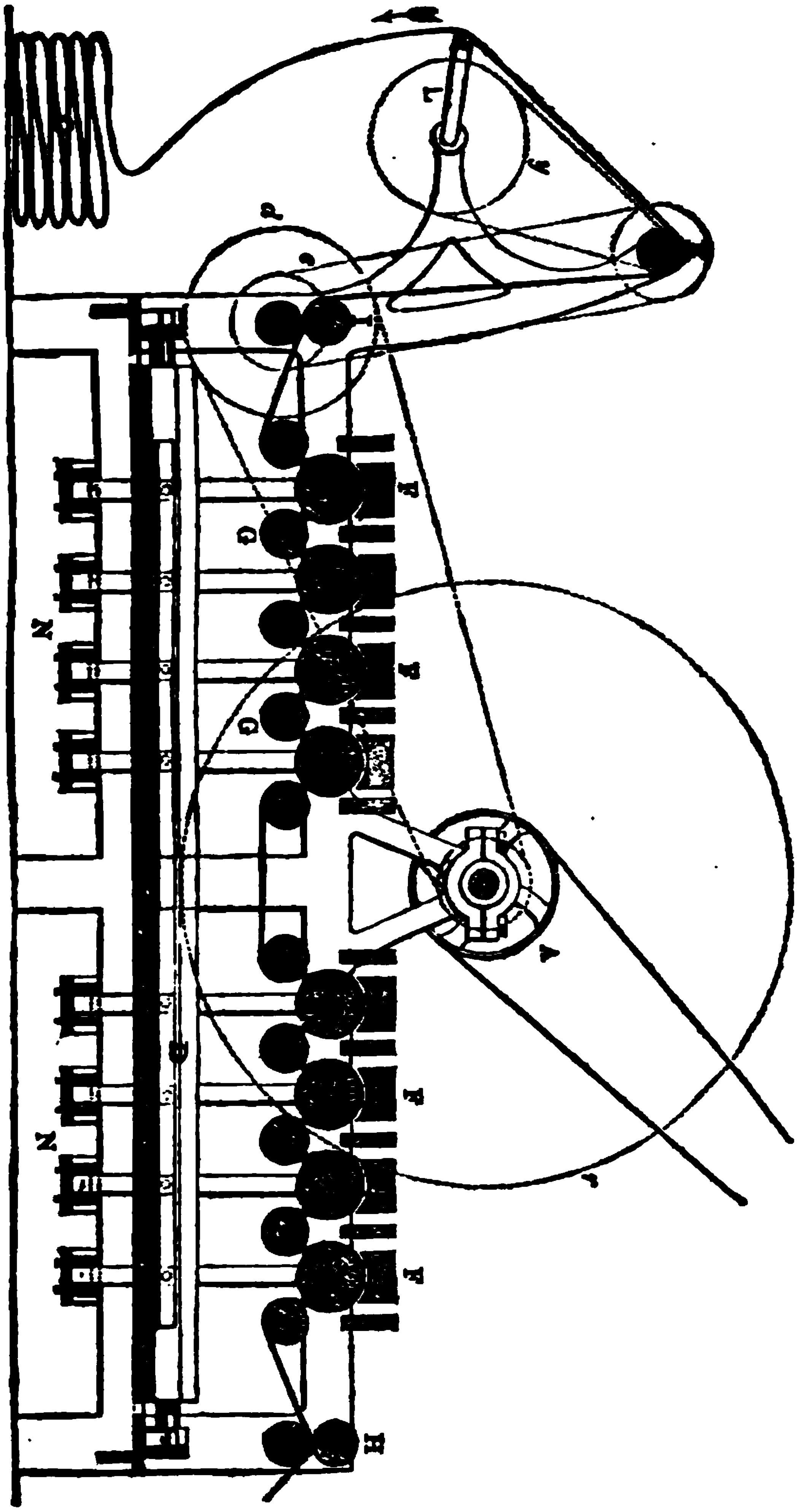


Fig. 111.—Machine for raising the Pile of Fustians. Longitudinal Section. Scale, about half an inch to the foot.

a fencer, upon the left foot. This process is repeated upon every adhesive line of the weft. After being thus ripped up, it is taken to the brushing or teazling-machine, to make it shaggy.

A, fig. 111, is the usual driving-rigger, or fixed and loose pulley, upon the end of the shaft, B. This shaft has a crank bent near its other end, which works the frame, D, up and down by means of the connecting link, C, fig. 112. E, E, are a series of wooden rollers, turning freely upon iron axles, and covered with tin-plate, rough with the burs of punched holes. F, F, F, are blocks of wood, whose concave under surfaces are covered with card-cloth or card-brushes, and which are made to traverse backwards and forwards in the direction of the axes of the revolving rollers, E, E, E, during the passage of the cloth over them.

G, G, G, are guide-rollers for the cloth. This is introduced between the feed-rollers at H, carried under the tension-rollers, G, G, and over the rough rollers, E, being drawn through the series by the discharging rollers at I. The two upper rollers at H and I are loaded with weights hung upon their axles; and the first have, besides, a brake to keep the cloth tightly distended in the machine, so that it may pass very slowly out from the discharge-rollers at I. These rollers are actuated by an endless strap from the pulley, *b*, upon the principal shaft, B, going round the pulley, *d*, upon the under roller at I, as shown by dotted lines in fig. 111. The blocks, F, F, F, get their motion from the straps, *m*, *m*, which pass over the rollers, M, fig. 112, and are made fast at *t*, *t*, to the frame, D. This frame vibrates up and down with the crank, C, of the shaft, B.

Fig. 112.—Machine for raising the Pile of Fustians. Cross Section
Scale, about half an inch to the foot.

r is a fly-wheel for equalizing the irregular movements of this powerful abrading machine.

The apparatus which lays down the piece of fustian in regular folds, remains to be described. The cloth passes over the roller, K, fig. 111, which is moved by a strap from the pulley, *e*, and afterwards goes over the eccentric rectangular frame, L, which slowly falls and rises by means of the pulley, *y*, and thus delivers the cloth as it comes forwards, in regular folds, upon the floor, as shown at *o*.

The driving-pulley, A, on the main or crank-shaft, B, makes about 150 revolutions in the minute.

The fustian, by passing through this machine, has its cut-up surface made uniformly shaggy.

Smooth fustians, when cropped or shorn before dyeing, are called moleskins; but when shorn after being dyed, are called beaverteen: they are both tweeled fabrics. Cantoon is a fustian with a fine cord visible upon the one side, and a satiny surface of yarns running at right angles to the cords upon the other side. The satiny side is sometimes smoothed by singeing. The stuff is strong, and has a very fine aspect. Its price is one shilling and sixpence a-yard.

Common plain fustian, of a brown or drab colour, with satin top, is sold as low as 7*d.* a yard.

A fustian, with a small cord running in an oblique direction, has a very agreeable appearance. It is called diagonal. Moleskin shorn, of a very strong texture, and a drab dyed tint, is sold at 20*d.* per yard.

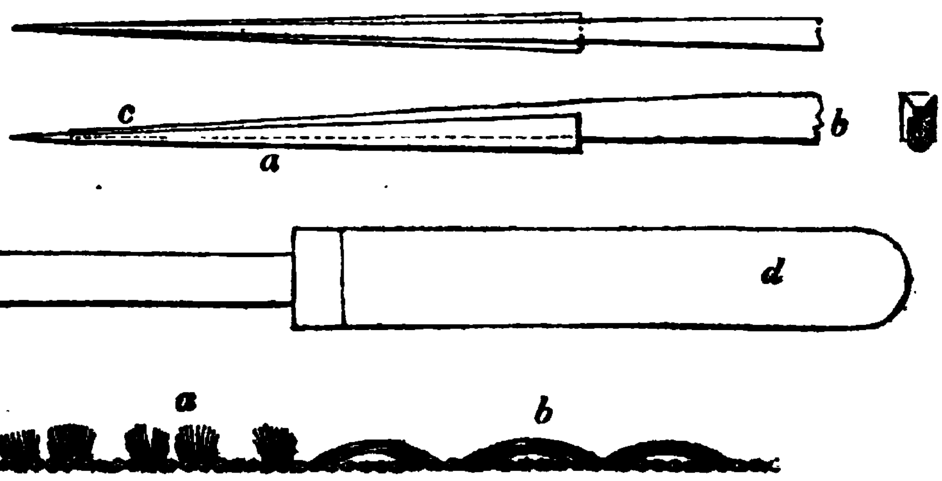


Fig. 113.——Knife for cutting the cords:—the broken ends *b*, *b*, should be joined.
Fig. 114.——Representation of the cords.

For the following catalogue of fustians I am indebted to Messrs. Leese, Kershaw, Callender, and Co., the eminent warehousemen, of Manchester:—

I.—Velveteens 27 inches wide.

1. As they leave the loom, with a downy surface on the one side and tweeled on the other.

2. Cut in fine parallel lines, velvety-looking on the cut side.
3. Singed, scoured, and dressed for dyeing.
4. Dyed and finished as black velveteens; a beautiful fabric. Price from 1*s*. 4*d*. to 2*s*. 9*d*. per yard.
5. Fired, scoured, and dyed, but not cut, as drab cantoon. Price 10*d*. to 21*d*.
6. Shorn, dyed, and finished, as drab beaverteen. 9½*d*. to 2*s*.
7. Shorn, dyed, and re-shorn, as moleskin. Price 10½*d*. to 2*s* 9*d*.

II.—Eight-shaft cord, vulgarly called corduroy.

1. As it leaves the loom, cord grooves partially filled with transverse yarns, back surface twilled and smooth.
2. Stiffened with glue for cutting.
3. Cut grooves, well defined and sharp. Surface of the cords velvety.
4. Brushed, singed, scoured, and dressed for dyeing.
5. Dyed and finished.

Eight-shaft can be made at prices from 6*d*. a-yard to 20*d*. The stuff is 18 inches wide when finished. If they be 27 inches wide, their price is from 13*d*. to 2*s*. 6*d*.

III.—Double Genoa cord, exists in

1, 2, 3, 4, 5, states, as the eight-shafts.

Their aspect is not dissimilar, but their texture is stronger. Their price varies from 7½*d*. to 21*d*., when 18 inches wide; and from 13*d*. to 2*s*. 6*d*., when 27 inches.

The weight of 90 yards of the narrow velveteen, in

the green or undressed state, is about 24 pounds. The goods made for the German, Italian, and Russian markets are lighter, on account of a peculiarity in the mode of levying the import duty in these countries.

Velveteens as they come from the loom, are sold wholesale by weight, and average a price of 20*d*. per pound. They are usually woven with yarns of Upland and Brazil cotton wool, spun together for the warp; or, sometimes, New Orleans alone. The weft is usually Uplands, sometimes mixed with East India cotton wools.

Trowser velveteens are woven 19 inches wide, if they are to be cut up; if not, they are woven 30 inches, and called beaverteen.

Cutting or cropping fustians by hand, is a very laborious and delicate operation. The invention of an improved apparatus for effecting the same end with automatic precision and despatch, was therefore an object of no little interest to this peculiar manufacture of Manchester. An ingenious machine, apparently well-calculated for this purpose, was made the subject of a patent by Messrs. William Wells and George Scholefield, of Salford, in November, 1834.

In the ordinary mode of working by hand, a single cord only is cut open at one operation, by the skilful workman guiding the knife along the piece, and keeping its point carefully in; but in this machine a series of knives are enabled to act simultaneously, and to cut many cords in width at the same time, from end to end of the piece, without interruption; the

corded fustian being extended upon rollers, and drawn progressively forward over the properly inclined stationary knives. There is, also, a provision in the event of any one of the knives slipping out of the cord in which it is intended to operate, or of passing through the fabric, or of being (by any knots in the cords) obstructed in its work, that the operations of the machine may be instantly stopped, in order that the error may be corrected before any further mischief ensues.

In an oblong rectangular cast-iron frame, two cylinders or drums are mounted horizontally, turning on axles supported in plummer blocks upon the side rails near the end of the frames.

Round the circumference of the one drum, the whole length of the piece of corded fustian is to be wound, in the first instance, and its end being then passed through the machine, and its waste-end or forcel made fast to the other drum, the rotation of this upon its axis will cause the length of the piece to be drawn forwards under the cutting knives, in winding it upon its circumference. The rotatory movements of these drums are produced by toothed wheelwork, mounted in the side rails of the frame.

Fig. 115, is a sectional representation of a part of the machine detached for the purpose of explaining

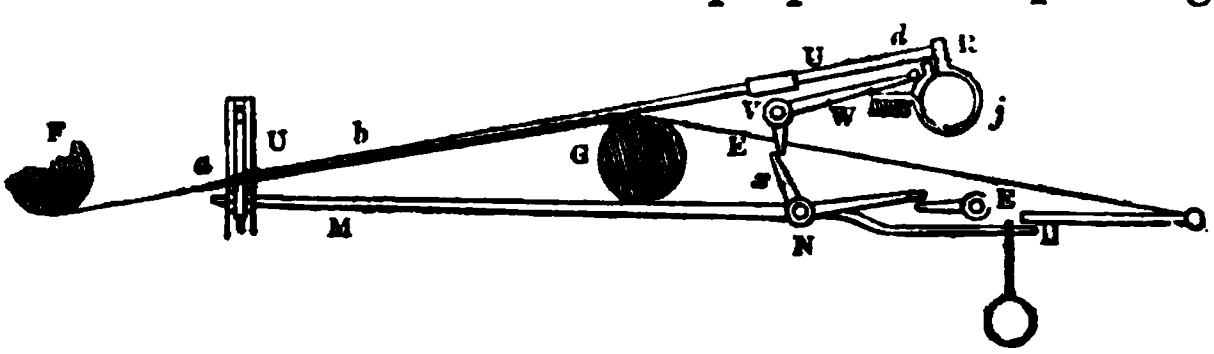


Fig. 115.—Machine for cutting Fustian by Power.

the cutting operation more clearly. Here only one of the knives is shown; the fustian-web, E, E, being stretched in the machine under the roller, F, and over the roller, G, for the purpose of laying it, and conducting it along under the knife, at such an angle, as may be desirable for applying the knives, as formerly represented, with the best effect to cut open the cords as the fustian advances.

A series of the knives, in any convenient number, are placed side by side in the machine, extending longitudinally as one knife is shown in the figure. The point of each knife so placed, is to be inserted into the rib or cord which it is intended to cut open, and the hinder part of each knife-handle is let into the socket or rest of a circular spring, *j*. A number of these circular springs, equal to the number of the knives, are to be fixed on a bar (shown in section at R) extending across the machine. Things being so arranged, the shaft of the drawing or winding-on drum (placed to the right hand of the figure) is to be put into geer with the driving power, and the other or feeding drum (towards the left hand in the frame) released, so as to turn freely round. As the web advances up the inclined plane, it will be cut open by the knives. The drum (about 20 inches in diameter) makes about nine turns in the minute.

A certain number of parallel cords having been thus cut from end to end of the piece, the right hand drum now covered with the fustian, is to be thrown out of geer, and the naked drum is made to revolve the reverse way, so as to re-wind the cloth from its fellow. This being done, the above operation is re-

newed on another parallel series of ribs in the fustian, till the whole be cut open.

If the point of one of the knives happens to penetrate through the cloth, it necessarily falls upon a transverse bar (not seen in this view) below the point, *a*. That bar is connected with the ends of arms or levers, M, M, extending from a shaft, N, which is mounted upon standards in the side frames of the machine; the transverse bar and arms, M, being balanced by weights upon the opposite side of the shaft, N, so as to enable that bar to be supported by very delicate spring catches in standard pieces, fixed to the sides of the frame-work.

When one of the knives falls upon the said transverse bar, its weight forces the bar down from its support in the spring catches, when the teeth of a small ratchet-wheel, which has been kept revolving, strikes against the fallen bar with such force as to cause a tail lever to cause the driving strap to shift to the loose pulley on the driving shaft; somewhat in the same way as the power-loom is stopped when the shuttle does not come home into its box.

If any obstruction (like a knot in the cord of the fustian) should come against the point of one of the knives in operation, as the fustian is drawn forwards, the resistance will force the knife back, and its spring-holder, *j*, giving way, will cause the hinder part of the socket, *d*, to strike against a transverse bar, R; and this bar being connected by arms with an axle, its recession will act upon certain levers, (not visible in this view,) which will shift the driving-strap to the loose pulley, as before.

In the event of any one of the knives jumping up out of the cord-channel which it was cutting, the force of the spring-holder, *j*, would project the knife forwards, and cause it to fall out of its socket, *d*, when the weight of the knife-handle as it falls, striking upon a transverse rod supported by arms, U, U, from a strap, V, will cause the arm, W, to force back the lever, *x*, extending from the axle, N, and thereby to raise the tail-piece, which shifts the driving-strap.

CHAPTER VI.

The Bobbin-Net Lace Manufacture.

SECTION I.

Historical Notices of it in connexion with Frame-Work Knitting, or the Stocking-Frame.

THE stocking-frame, to any one who attentively considers its complex operations, and the elegant sleight with which it forms its successive rows of loops or stitches, will appear to be the most extraordinary single feat,—the most remarkable stride, ever made in mechanical invention. In the Stocking Weavers' Hall, in Red Cross Street, London, there is a portrait of a man, painted in the act of pointing to an iron stocking-frame, and addressing a woman, who is knitting with needles by hand. The picture bears the following quaint inscription:—"In the year 1589, the ingenious William Lee, A.M., of St. John's College, Cambridge, devised this profitable art for stockings, (but being despised, went to France,) yet of iron to himself, but to us and to others, of gold; in memory of whom this is here painted."

It was only twenty-eight years prior to the construction of this machine, that the art of knitting stockings, by wires worked by the fingers, had been introduced into England from Spain.

According to one story, Lee was expelled from the University for marrying contrary to the statutes. Having no other means of subsistence, he and his wife

were obliged to live on her earnings as a stocking-knitter; when, under the pressure of want, Lee contrived his frame as a method of multiplying production.

But the following is probably a more correct account of the origin of this contrivance. According to an ancient tradition in the neighbourhood of Lee's birth-place,* the stocking-frame was meditated under the inspiration of love, and constructed in consequence of its disappointment. Lee is said to have been in early youth enamoured of a fair mistress of the knitting craft, who had become rich by employing a number of young women at this highly-prized and lucrative industry. The young scholar, after studying fondly the dexterous movements of the lady's hand, had become himself not only an adept in the art, but had imagined a scheme of making artificial fingers for knitting many loops at once. Whether this feminine accomplishment excited jealousy, or detracted from his manly attractions, is not said; but his suit was received with coldness, and then rejected with scorn.

Revenge now prompted him to realize the ideas which love had first inspired. He devoted his days and nights to the construction of the stocking-frame, and brought it, ere long, to such perfection, that it has remained nearly as he left it, without receiving any essential improvement. Having taught its use to his brother and the rest of his relations, he established his frame at Culverton, near Nottingham, as a formidable competitor of female handiwork, teaching his mistress, by the insignificance to which he reduced the

* Woodborough, seven miles from Nottingham.

implements of her pride, that the love of a man of genius was not to be slighted with impunity.

After practising this business during five years, he had become aware of its importance in a national point of view, and brought his invention to London to seek protection and encouragement from the Court, by whom his fabrics were much admired. The period of his visit was not propitious. Elizabeth, the patroness of whatever ministered to her vanity as a woman, and her state as a princess, was in the last stage of her decline. Her successor was too deeply engrossed with political intrigues for securing the stability of his throne, to be able to afford any leisure for cherishing an infant manufacture. Nay, though Lee and his brother made a pair of stockings in the presence of the King, it is said that he viewed their frame rather as a dangerous innovation, likely to deprive the poor of labour and bread, than as a means of multiplying the resources of national industry, and of giving profitable employment to many thousand people.

The encouragement to English ingenuity which the narrow-minded pedant, James, refused, was offered by Henry IV. and his sagacious minister, Sully. They invited Lee to come to France with his admirable machines. Thither, accordingly, he repaired, and settled at Rouen, giving an early impulsion to manufactures which has conduced not a little to their great development since, in the department of the Lower Seine. After Henry had fallen a victim to domestic treachery, Lee, envied by the natives whose genius he had eclipsed, was proscribed as a Protestant, and obliged to seek concealment from the bloody bigots in Paris, where he ended his days in secret grief and

disappointment. Some of his workmen made their escape into England, where, under his ingenious apprentice, Aston, they mounted the stocking-frame, with some improvements, and thus restored to its native country an invention which had been well nigh lost to it.

The first frame was brought into Leicestershire in the year 1640, and thus laid the foundation of the hosiery trade of that county, since so prodigiously enlarged in it and the adjoining counties of Nottingham and Derby.

In the year 1663, Charles II. granted to the Framework Knitters' Society of London, a charter, which had been refused to them a few years before by Oliver Cromwell.

Jedediah Strutt, the founder of the distinguished house of Belper, invented, in the year 1758, a machine for making ribbed stockings. About that time he settled in Derby, and established that manufacture under protection of a patent, in conjunction with his brother-in-law, Mr. Woollatt, a hosier of that place. During a portion of the patent period, Mr. Samuel Need, of Nottingham, was a partner in the concern. The patent right was twice tried in Westminster Hall; first by the hosiers of Derby, and next by those of Nottingham; after which it was quietly enjoyed by the patentee till the end of the term of fourteen years. This improvement suggested several more, such as open-work mittens, and fancy articles in the stocking stitch.

Lee's frame was exceedingly simple, being a *twelve gage,* with jacks only. Aston, of Thornton, a miller by trade, added the lead-sinkers, which are still in use.

The trucks were placed on the sole-bar by Needham, a frame-work knitter in London; and the caster-back and hanging bits were added by Hardy, another London artisan, about the year 1714. Thus the stocking-frame seems to have reached a nearly perfect state, for it has acquired no new powers or facilities of operation from any subsequent contrivance. The Derby rib-machine, applied to the stocking-frame, is called, by the trade, the one-and-one and the two-and-one rib-machine.

There is a manufactory of hosiery at Belper which is supposed to be the most extensive in the world. It employs about 400 silk stocking-frames, which produce 200 dozen pairs of hose weekly, and 2,500 cotton hose frames, each turning off, on an average, nine pairs weekly, the whole amounting to little less than *one hundred thousand dozens* in the year.

The principle of the stocking-frame was applied to the knitting of various other articles in the course of the last century. In 1766, Crane manufactured a rich brocade for waistcoats on a similar frame; and about two years thereafter he attempted vandyke work, by appending a warp-machine to a plain stocking-frame. Mr. Robert Frost, of Arnold, near Nottingham, invented the figured eyelet-hole machine; and, in concert with Mr. Thomas Frost, now of Worcester, he obtained patents for various inventions, which led the way to the net and lace-frames.

The first machine for making lace with a stocking-frame was constructed in 1777, which has been claimed both by Mr. Robert Frost and by Holmes, a poor workman of Nottingham. This was, ere long, superseded by the point-net machine, the ingenious invention

of Mr. John Lindley, senior. On the death of this individual, Mr. Taylor, of Chapelbar, secured a patent for an improvement on the same principle. A still further improvement on this machine was made by Mr. Hiram Flint. At the beginning of the present century, nearly the whole of machine-made lace was produced from these point-net machines—mechanisms probably more delicate than any other ever used for manufacturing purposes, either in this country or elsewhere. There were no fewer than 1,000 such machines then in active work.

In the year 1802 or 1803, the manufacture of lace-net from the warp-machine was successfully revived by some individuals in Nottingham. This kind of lace had been formerly made by an ingenious workman called Dawson, the inventor of the brace machine, but had been discontinued for some reason not generally known. Several important improvements began now to be made on it, which gave to this modification of network such value, that, in 1808, it competed in the market with point-net.

Notwithstanding this advance of the Nottingham lace-trade, the fabric was always considered to derive its principal merit from its imitation of the bobbin or cushion-lace. The resemblance was, however, very imperfect, as the net made of cotton thread was greatly inferior in strength, durability, and transparency to the proper lace fabric. To remedy these imperfections became, therefore, an object of pursuit to many ingenious artisans, and liberal encouragement was afforded towards its attainment by the lace manufacturers of Nottingham, and particularly by Mr. Nunn. Any person who undertook to construct, on feasible principles,

a machine capable of making bobbin-net lace, was zealously patronized. Most sober-thinking persons, however, regarded the project as akin to the perpetual motion,—a thing not to be realized.

Among the many individuals who devoted their minds to the subject was John Heathcote, of Loughborough, a stocking-weaver by trade, who had studied for some time the mode of mounting the net-machinery of Nottingham. To him belongs the distinguished honour of solving this very difficult problem, and of practically demonstrating that a machine might be made to satisfy the wants and wishes of the trade. His first operative frame was the result of many troublesome trials, which would have baffled a man of ordinary talent and enterprise. At length, in the year 1809, he had matured his plans so far as to warrant his securing the exclusive use of them by a patent, famous for its pecuniary productiveness to him and his partner, Mr. Lacey; as also for its being the fruitful parent of many mechanical constructions eminently subservient to the trade and commerce of the kingdom.

Without meaning to impugn the merit of Mr. Heathcote, it may be stated that the principle of his patent had been embodied, since the year 1803, in a machine for making fishing-nets, the invention of Robert Brown, or his partner, George Whitmore, both of Nottingham. "This machine possesses all the essential principles and properties of Heathcote's patent bobbin-net machine, and is, in fact, to all intents and purposes, a bobbin-net machine*." To this machine must be traced

* Mr. Morley, the very eminent bobbin-net lace-manufacturer, of the great firm of Boden and Morley, of Derby, pronounces this judgment.

the origin of the curious invention of the bobbin and carriage: to it also must be referred the method of using two divisions of threads, the warp and the bobbin; and to it alone must be attributed the beautiful idea of passing, or, as it is generally termed, twisting, two divisions of threads, with order and regularity, and without entanglement, distinctly round each other. The specification of Robert Brown's patent for this machine was enrolled at the Patent Office, and may, therefore, be referred to as an undoubted document.

The idea of reducing the thickness of the bobbin and carriage to a scale fit for the fine meshes of bobbin-lace, seems to have originated with Edward Whittaker, of Radford, who, being acquainted with Robert Brown, had obtained a knowledge of his fishing-net machine. Whittaker was assisted in realizing his project by Messrs. Hood and Taylor, then lace manufacturers in Nottingham, who sent him over to Loughborough, partly with the view of removing him from the Nottingham mechanics, but principally to place him in communication with Mr. Hood's brother, a frame-smith at that place, who was to execute the iron work of the machine. After some time, Messrs. Hood and Taylor grew weary of the undertaking, when Charles Hood, of Loughborough, retained possession of the apparatus, on the score of debt due to him, and thereafter sold it to Mr. Heathcote for the paltry sum of 8*l.* or 10*l.* This gentleman, having thus obtained an acquaintance with several elementary principles of lace-making, applied himself diligently to their practical combination, and, in the following year, patented his very ingenious bobbin-net machine. Like most other novel mechanisms, this one, however cre-

ditable to the talent of the patentee, was complicated with many distinct movements, and effected its end by very circuitous means. The manufacture of lace by it was slow and expensive, in consequence of its imperfect mode of making the selvages, and by the employment of stretchers, or long strips of wood, pointed at each end with pins, for the purpose of preventing the net from running in at the edges. The workman was thereby obliged to stop work at every four or five holes, in order to adjust his bobbin, and replace the stretchers. In spite of these defects, the machine commenced a new era in the manufacture of lace, and shewed itself to great advantage alongside of the method of making it by hand upon the cushion. The prospects thus opened up, induced many workmen to devote their skill to lace-machinery. Accordingly, in 1810, John Brown, of Nottingham, invented his celebrated traverse-warp machine,—one admirably adapted for making a number of narrow breadths, or strips of lace, but not fitted for the manufacture of broad fabrics. It was, moreover, a delicate and expensive apparatus, difficult to manage and adjust.

In the year 1811, Mr. William Morley, also of Nottingham, invented his straight bolt machine, more simple in construction, more concentrated and easy in the movements than its predecessors; circumstances which, with the improved method of changing the bobbins upon the selvage, and the introduction of the spur or selvage-wheels for the lace to run over, gave Morley's machine a great superiority over Heathcote's. The horizontal movement of this mechanism, however, occasions an alternate tightening and slackening of the bobbin-threads, and a corresponding imperfection in

the appearance of the net, unless constant care be taken by the workman.

The pusher machine was invented in the same year by Samuel Mart and James Clark, of Nottingham. It was used for a long time, by many persons, for making narrow edgings of lace. It undoubtedly possesses peculiar advantages, but is costly and delicate in construction, and subject to many inconveniences, which render it unsuitable for general use. The following year is remarkable in the history of the lace trade for the invention of the circular bolt machine, by Mr. Morley,—a mechanism possessing all the advantages of his straight bolt machine, without its disadvantages.

About the same time, Mr. John Leavers, sen., of New Radford, brought forward the lever machine, conjointly with one Turton, of the same place. This apparatus bears a strong resemblance to Mr. Heathcote's in many prominent features, and cannot, therefore, be considered as forming a distinct invention; but may be designated as a single-tier Loughborough machine. It deserves particular notice, however, in consequence of its general adoption by the trade. As originally constructed, it stood in a horizontal position, somewhat like one of the other machines lying on its side. This difference is supposed to have been given in order to make it look as much as possible unlike to Heathcote's, with the intention probably of evading his patent right, rather than from any advantage it could derive from that position. On the contrary, it was hereby subject to many disadvantages, and was, in consequence, changed to the upright posture, by Mr. John Leavers, jun., son of the former. After all,

the general aspect of this machine is awkward, its movements complex, and its adjustments delicate—disadvantages, however, more than counterbalanced by the good quality of its fabric.

Many alterations and improvements have been since made in lace machinery, but nothing which deserves detailed notice, except the working of it by power. The first attempt of this kind was due to John Lindley, of Loughborough, who constructed a machine possessing the properties of the lever and traverse-warp machines combined. He worked it by a rotary movement, at Tottenham, near London, in conjunction with Mr. C. Lacey, the original partner of Mr. Heathcote; but the project was so unsuccessful, as to ruin those concerned. About the same time Mr. Heathcote applied the rotary movement to the circular bolt machine, and mounted a manufactory on that principle, at Tiverton, in Devonshire. A few years thereafter, several other establishments sprung out of the same place, and settled in Devon and Somerset, constituting a considerable body of lace manufactories in the West of England.

The persons who have distinguished themselves most in the department of lace machinery as a part of the factory system, are Mr. Heathcote, Mr. Morley, Mr. Sewell, Mr. William Jackson, and Mr. William Henson. William Mosely, of Radford, attempted to work the lever machine by a rotary motion without success; others, who made a similar attempt with the pusher and traverse-warp machines, met with no better fate. It is a remarkable fact, highly creditable to the mechanical sagacity of Mr. Morley, that no machines, except those on the circular bolt principle, have been

found capable of working successfully by mechanical power.

The number of twist-lace machines at work in this country may be estimated at upwards of 4,000, of which the majority are constructed either on the circular bolt or lever principle. Heathcote's patent machine, known by the name of the Loughborough, or, more properly, the Old Loughborough, may be considered to be entirely obsolete. The number of traverse-warp machines is not considerable, and is on the decline. The pusher machines are very limited in number, but they are kept up on account of a kind of lace, called a Grecian net, a showy fabric, for which they are peculiarly adapted.

The quantity of bobbin-net lace now produced in the kingdom is prodigious, and has caused a depression of prices quite unparalleled in any other department of the cotton-trade. Four-fourths lace was sold in 1809 by Messrs. Heathcote and Lacey for five guineas a-yard. Lace of a better quality may now be purchased for 1*s*. 6*d*. Quillings, or narrow edges of lace, as first made by the traverse-warp machine, three inches broad, were sold in 1810 for 4*s*. 6*d*. a-yard; and they are now selling, of a better fabric, for 1½*d*.

Besides the lace machines in Nottingham, Loughborough, and in the West of England, there are in the town of Derby alone 150, of which those in the beautiful factory of Messrs. Boden and Morley turn off fully 40,000 square yards per week, a quantity capable of covering eight acres of land.*

* See Statistics of the Bobbin-Net Trade in Book IV.

SECTION II.

Bobbin-Net Lace Manufacture.

The annals of industry offer no example of such remarkable vicissitudes in the wages of labour, and no such instructive lessons of the influence of mechanical improvement to lower the remuneration of the few, while it multiplies the employments of the many, as the manufacture of bobbin-net lace. For several years after its first commencement, about the year 1810, it was no uncommon thing for an artisan to leave his usual calling, and, betaking himself to a lace-frame, of which he was part proprietor, realize, by working upon it, 20*s*., 30*s*., nay, even 40*s*. a-day. In consequence of such wonderful gains, Nottingham, the birth-place of this new art, with Loughborough, and the adjoining villages, became the scene of an epidemic mania. Many, though nearly devoid of mechanical genius, or the constructive talent, tormented themselves night and day with projects of bobbins, pushers, lockers, point-bars, and needles of every various form, till their minds got permanently bewildered. Several lost their senses altogether; and some, after cherishing visions of wealth, as in the old time of alchemy, finding their schemes abortive, sunk into despair and committed suicide.

Such has been the progress of mechanical improvement in the lace manufacture, that the cost of labour in making a *rack*, which was, twenty years ago, 3*s*. 6*d*., or forty-two pence, is now only *one penny*. One of Mr. Morley's overlookers informed me that he had been, a few years ago, proprietor of a lace ma-

chine, for which he had paid 230*l*., and by which he could earn 30*s*. a-day, which he sold two months before the time I saw him (in October, 1834), for *two pounds*.

The prices of this beautiful fabric have fallen, as already stated, in an equally remarkable manner. Twenty years ago a 24 rack piece, $\frac{5}{4}$ broad, fetched 17*l*. in the wholesale market; it is now sold for 7*s*. Such are the wonderful achievements of machinery!

Ordinary bobbin-net resembles in its texture the plainer kinds of pillow-made lace. The threads, as we have said, are entwined together, so as to form perfectly regular six-sided holes, the two opposite sides of which, the upper and under, lie in the direction of the breadth of the piece, so as to stand at right angles with the selvage, or border line.

Figure 117 will serve to explain clearly how those regular and equal-sized hexagons are produced by the crossing and intertwisting of the threads. Here we see, upon a magnified scale, how the fabric results from the conjunction of three lines of thread; one of which proceeds from above downwards, in a winding path; another of the lines runs towards the right, and a third to the left, both of them, also, in zig-zag directions. These obliquely-disposed threads wind round the up-and-down or warp-threads, and also cross each other in the interval betwixt the warp, both after a like manner, which may be clearly understood by inspecting the figure, without further explanation. The warp-threads are, as above stated, extended at first in straight perpendicular lines in the machine, and derive their serpentine curvatures, in the course of the work, from the tension or draught of the obliquely-

disposed weft-threads, by which they are alternately drawn to the right and the left during the interlacement. If we suppose these warp-threads to be inflexible wires, the fabric would have, consequently, the appearance represented in fig. 26; and although it does not really resemble that drawing, yet the manner of entwining the threads will be more readily apprehended from the inspection of that sketch. The warp-threads proceed in the direction, *a a*, *a' a'*, *a'' a''*; the one half of the bobbin, or weft-threads, takes the direction *b b*, *b' b'*, *b'' b''*; and the other half crosses round the first half, in pursuing the winding path, *c c*, or *c' c'*, towards the opposite border of the web. In tracing the route of a single weft-thread, we shall find that it persists in the same course till it reaches the last or outermost warp-thread, around which it winds itself, not merely once, as it has done round the other warp-threads, but twice, and then turns back to wind itself in the opposite direction. This return of the weft-threads forms the selvage of the piece.

The beauty of bobbin-net lace depends, not only upon the quality of the threads, but principally upon the perfectly hexagonal shape of the holes, and equality of their sizes. The nearer the warp-threads lie alongside of each other, the smaller are the holes, and the finer looking is the lace. The number of warp-threads in a piece one yard wide may vary from 700 to 1,200, which corresponds to from about 20 to 34 in the inch. The breadths of the holes cannot, however, be directly deduced from these numbers, because the holes are enlarged by the serpent-like bendings of the warp-threads.

Bobbin-net is usually brought into the market in

pieces, of from 20 to 30 yards, or even more, in length, and of very variable breadths. The narrow ribands of bobbin-net, called quilling-lace, or ruffles for cap-borders, from about the breadth of the finger to that of the hand, are worked in many breadths at a time in the same machine, in which the warps of the different quillings are stretched in the same vertical plane, and are connected together in the working, in order to prevent, by their mutual tension, those irregularities in the forms of the meshes, which would be apt to happen in the crossing of the weft, if they were woven separately. This temporary conjunction is made by means of a single warp-thread destined for that purpose, which is drawn in a zig-zag direction from the border of one riband to its neighbour, being entwined by the weft with both. When the fabric is formed, by cutting and drawing out these union threads, the quillings become distinct pieces.

The different systems of bobbin-net lace machinery, all of which have been invented, or at least been made practicable, since about the year 1810, may be referred to the following heads:—

1. The Old Loughborough double tier, or Heathcote's.
2. The single tier, on Stevenson's principle.
3. The improved double tier, or Brailey's.
4. The single tier, on Leaver's principle.
5. The Old Loughborough improved, with pumping tackle.
6. The pusher principle.
7. The traverse-warp, or Brown and Freeman's machine.

8. The traverse-warp rotary, or Lindley and Lacey's.
9. The straight bolt, or Kendal and Morley's.
10. The circular bolt of Mr. Morley.
11. The circular comb, or Hervey's.
12. The improved levers.

The above-named machines comprehend the greater part of the principles upon which the apparatus for manufacturing lace have been founded. Steam-power has been applied to three of them; to the circular comb machine, or Hervey's; to the circular bolt machine, and to the straight bolt machine.

Before describing the circular bolt double-tier machine, with two sets of bobbins, it may help to communicate a clearer conception of the bobbin-net fabric, if we first describe the changes of position among the threads upon the single-tier system. The operation is, however, quite similar in both machines.

In the original machine, on the pusher principle, commonly called Crowder and Days' *improved pusher*, first introduced in the year 1820, fourteen general motions of the mechanism were necessary to complete the intertwisting of the threads in the formation of one hole or mesh; but in another form of the same machine, made the subject of a patent by Mr. Joseph Crowder, of New Radford, near Nottingham, in May, 1825, only ten motions are required to effect the same object. These improvements may be referred to three principal heads; 1. The employment of two series of pushers upon each side of the machine, to push the bobbins across between the warp-threads, backwards and forwards; these are attached to two distinct bars

in front, and to two in the back of the machine, which are called the upper and lower front and back pusher-bars. 2. The employment of a single guide-bar for conducting the whole series of warp-threads in place of two which had been previously used; it derives its lateral traverse movement called *shogging*, from certain cam-wheels. 3. The introduction of two bars called *locker-bars, or fetchers,* similar to the bars employed for completing the transfer of the bobbins across the upright plane of the warp-threads, which had been partially driven through by the pushers. The bobbins are represented in their places at G, G, in plate X., fig. 1; and separately, in the same plate, figs. 3 and 4. The slits, called *gates*, in the bolts or combs in which they travel backwards and forwards across the warp are shown separately in fig. 6, and at *k, k'*, in fig. 1 of the same plate. In that species of machine there are two sets of bobbins, the working of which will hereafter be explained. For our present illustration, only one row of bobbins is to be considered.

The progressive formation of the meshes through the operation of these ten movements will be rendered more intelligible by the following development, taken along with the following figures, 116, 117, 118,—128.

These sketches represent the relative positions of the main parts of the machine, before the lace-weaving begins, and also after each of the ten movements. The number of warp-threads introduced for the purpose of our explanation is eight; it may be increased to any amount by the fancy of the reader. These threads are marked with numbers in their natural order; as well as the bobbin-carriages, which are introduced

through the gates or channels of the bolts in the lines between the warp. To make the station of the carriages manifest, those anterior to the warp upon the front bolt or comb are drawn in full lines; those behind the warp, upon the back bolt, in dotted lines. The two strong lines, *j, j, j, j, k, k, k, k,* denote the front pusher-bar, and the letters of the alphabet, the

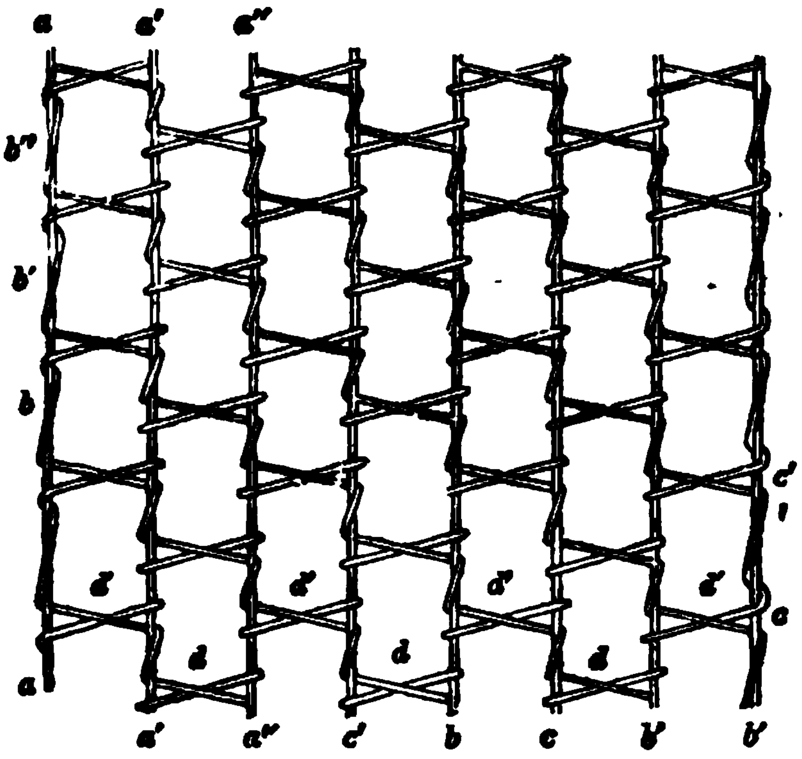


Fig. 116.—Bobbin-Net Lace Meshes.

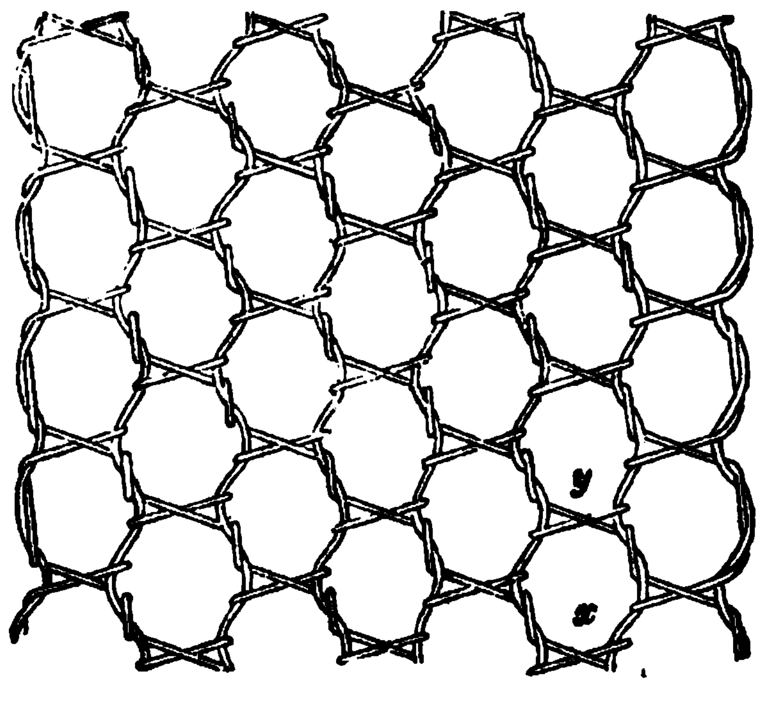


Fig. 117.—Bobbin-Net Lace Meshes.

pushers themselves; under the dotted lines, *h, h, h, h, i, i, i, i,* we may figure to ourselves the two back pusher-bars. In the machine, these back and front pushers are placed at the same height, and upon a level with the bobbin-carriages. This position could not, however, be represented in the present figures, but the imagination will readily supply this deficiency. The relative dimensions of the parts may be thrown entirely out of view, without affecting the illustration.

At the commencement of the operation, all the parts of the machine are supposed to be in the state figured in 118. The driving arms are placed so that the front pushers, *j, k,* are near to the warp; all the bobbin-carriages are stationed upon the back bolt (as *k',* plate IX., fig. 1.) The front pushers, upper and under, stand in pairs, the one right over the other; the back pushers are shoved towards each other so that a pusher is opposite to each carriage. The front locker, or fetcher-bar, is raised up, the back one is in its lowest position. The warp-threads are stretched in a vertical plane (*see* F, plate X., fig. 2.) To each of

1 2 3 4 5 6 7 8

Fig. 118.

them a weft-thread is twisted fast underneath. The ten motions by which a row of meshes or holes is formed obliquely across the whole piece, proceed in the following manner:—

1. The whole series of bobbins are moved from the back to the front bolt, drawing along with them all the weft-threads, through the intervals of the warp-threads, at the same time that a horizontal roller on the lower part of the machine makes a tenth part of a revolution. The warp is moved one gate or bolt-space to the left by the traverse of its guide-bar; whilst the two bars with the bolts, and the pushers *k*, *i*, *h*, remain in their places. The position of the several parts now is as represented in fig. 119. Each of the bobbin-carriages has, at present, one of the front pushers, *j*, *k*, before it, the last carriage (8) excepted. The warp-threads have, in consequence of the traverse of the guide-bar taken an oblique direction, and hence the carriages are placed in such a position that at their next passage through the warp they may go by the right side of those warp-threads from whose left side

I.

1 2 3 4 5 6 7 8

Fig. 119.

they had last emerged. In order to perceive this more plainly, we have only to compare the positions of the carriages 1, 2, 3, &c., with the warp-threads marked with the same numbers in fig. 118 and 119.

2. At the second movement the pushers, *j*, *k*, advance towards the warp, and push the whole of the bobbin-carriages, with the exception of the last, (upon which no pusher is acting,) from the front to the back bolt, on to which the fetcher-bar draws them. The bobbins, as we have said, return now by the right of those warp-threads by whose left they originally passed. The back bolt, with the carriages resting on it, is moved a gate to the left, and the lower back pusher-bar a side-step to the right. The pushers *h*, *j*, *k*, the front bolt-bar and the guide-bar remain at rest. Fig. 120 represents the position of all the parts after the second movement.

3. At the third movement, the back pushers, *h*, *i*, which now stand in pairs nearly over each other (*see* fig. 120,) drive only the half of the bobbin-carriages (those which are marked with the odd numbers, except No. 1,) forwards through the warp, and to the

II.

1 2 3 4 5 6 7 8

Fig. 120.

left of their respective warp-threads. The pusher-bar *j*, moves one side-step to the right; the guide-bar does the same; all the other bars remain unmoved. Fig. 121 shows the position of the parts after the third movement. The warp-threads are once more vertical, and one-half of the bobbin-carriages are placed upon the front bolt, and one-half upon the back bolt; the front and back pushers stand in pairs over each other.

4. The condition of the front pushers, *j*, *k*, is the cause of their making an empty, that is, as to the disposition of the bobbin-carriages, an inoperative movement, since they pass free between the front gates, and cannot reach their opposite carriages that are standing upon the back bolt. A glance at fig. 121 will remove all doubt in this respect. The front bolt, with the half number of the bobbins standing in it, moves one gate to the left, and the back bolt, with the other half of the bobbins, moves one gate to the right, at the same time, the front pushers, *j*, *k*, make a side-step to the left, to get out of the way of the bobbins, which might otherwise strike them on the sides. The back pusher-

Fig. 121.

bar, and the guide-bar remain at rest. Fig. 122 shows the changes introduced by the fourth movement.

5. The remaining half of the bobbin-carriages are shoved through the warp from the back to the front bolt, to the left of their warp-threads. The upper front pusher-bar, *j*, traverses one step to the right, the under front pusher-bar, *k*, two steps to the right, the front bolt with the bobbin-carriages one step to the right, and the guide-bar one step to the left. The back bolt, and the two back pusher-bars, *h*, *i*, remain still. The third to the fifth movements have crossed the threads of the bobbins round the threads of the warp. In fig. 116 these crossings are marked with *d*. It is necessary to make these fast before the work proceeds further. The needles upon the point-bars serve for this purpose (*see* explanation of plate IX., fig. 2). At the moment when the fifth motion has completed the crossing of the threads, the front point-bar applies its needles to that crossing, and keeps it fast. The motion of the point-bar is a compound one, for its needles must be withdrawn from the web in a truly

IV.

1 2 3 4 5 6 7 8

Fig. 122.

horizontal direction, and then be lifted up. With the downward pressure of the thread-crossing by the point-bar the first half of the row of meshes is completed. The present position of the parts of the machine is shown in fig. 123. The sections of the needles which hold down the crossings of the threads are here represented like small circles, in order to make the crossings obvious.

6. At the sixth movement the front pushers, *j*, *k*, shove all the carriages from the front to the back bolt, with the exception of the first, which is left alone behind. The under pusher-bar of the back pair, *i*, moves one step to the left, and the guide-bar one step to the right, while the other bars remain at rest. Fig. 124 shows the positions thence resulting.

7. The seventh movement brings all the bobbin-carriages from the back to the front, in which they pass on the left side of their respective warp-threads, on whose right they were at the sixth movement. The under front pusher-bar, *k*, moves one step to the left, the guide-bar also one to the left, the back-bolt, which

V.

1 2 3 4 5 6 7 8

Fig. [illegible].

is empty, also moves one step to the left. All the other bars remain in their places (*see* fig. 125).

8. At the eighth movement one-half of the bobbin carriages (in the order of their station, 1, 3, 5, 7, &c.) move from the front to the back bolt, as no pushers of the bar, *j, k,* stand opposite the other carriages. The carriages now pass each one to the right of its warp-thread. The guide-bar takes a step to the left, and the pusher-bar, *i*, a step to the right, while the other bars remain at rest (*see* fig. 126).

VI.

1 2 3 4 5 6 7 8

Fig. 124.

VII.

1 2 3 4 5 6 7 8

Fig. 125.

9. At the ninth movement the back pushers come forward alone—that is, without striking the bobbin-carriages, one-half of which stand upon the front, and the other upon the back bolt. The front bolt now moves one step to the left; the back bolt and the two back rows of pushers, *h*, *i*, move one step to the right; the other pushers and the guide-bar remain unmoved (*see* fig. 127).

10. The tenth movement drives the half of the bob-

VIII.

1 2 3 4 5 6 7 8

Fig. 126.

IX.

1 2 3 4 5 6 7 8

Fig. 127.

bins which are upon the front bolt from these to the back bolt, by the right-hand side of their warp-threads. The back upper pusher-bar, *h*, takes a step to the left, the back under pusher-bar, *i*, takes two steps to the left, the front bolt, which is empty, one step to the right, the guide-bar two steps to the right, while the back bolt bar and the two front pusher-bars remain in their places. The eighth, ninth, and tenth movements have again effected a crossing of the weft-threads given out by the bobbins (*see* fig. 116, *d'*, *d'*, *d'*, *d'*). At this moment the back point-bar, in like manner as the other point-bar formerly, withdraws its needles from the web, and lifts them up. Thereafter, by its depression, the needles are applied and pressed down upon the new fabric, so as to complete the mesh or row of holes.

After the tenth movement the roller which moves the bolts and bars is in the same position as it was at the beginning of the first movement. All the other parts are also in their primary situations, namely, the guide-bar, the pushers, and the bolts, as may be per

X.

1 2 3 4 5 6 7 8

Fig. [illegible]

ceived by comparing figures 118 and 128. These ten movements being repeated, a second row of meshes is produced.

With respect to the carriages with the bobbins, they stand in one row, after the tenth movement, just as they did at the beginning: yet they have changed their places relative to each other; for that bobbin which was formerly the first in the range is no longer so. If we consider, in fig. 116, the course of the weft-threads, we shall remark the necessity that the bobbins of every thread, by going in the direction *c, c,* or *c′, c′,* after every crossing, must stand one step further to the right, and also in other gates, or betwixt other bolts. In this way, but towards the left hand, those bobbins must proceed which belong to the threads running in the direction *b, b, b′, b′,* &c. This march becomes on both sides a countermarch when the bobbin-carriage arrives at the selvage of the web; it then returns, and pursues its way backwards until it reaches the opposite border. In this manner a continual interchange of places occurs among the bobbins, and indeed this change happens every time at the fourth and ninth movement, when the bobbin-carriages are parted upon the two bolt-bars, and one of these bars is shogged to the right, and the other to the left.

The bobbins at the beginning of the fabric (*see* fig. 122) are marked with continuous numbers, but, for the sake of illustration, only eight bobbins are employed. If we follow all their changes of place during the ten movements, and mark those bobbins which are stationed upon the back bolt with an asterisk, we shall have the following diagram:—

	Position of the Bobbins.							
At the commencement .	*1	*2	*3	*4	*5	*6	*7	*8
After the 1st movement .	1	2	3	4	5	6	7	8
„ 2nd „ .	*1	*2	*3	*4	*5	*6	*7	8
„ 3rd „ .	*1	*2	3	*4	5	*6	7	8
„ 4th „ .	*(1) (3)	*2	5	*4	7	*6	8	
„ 5th „ .	*1	3	2	5	4	7	6	8
„ 6th „ .	*1	*3	*2	*5	*4	*7	*6	*8
„ 7th „ .	1	3	2	5	4	7	6	8
„ 8th „ .	*1	3	*2	5	*4	7	*6	8
„ 9th „ .	3	*1	5	*2	7	*4	8	*6
„ 10th „ .	*3	*1	*5	*2	*7	*4	*8	*6

The two figures standing over each other in the fifth line show that here two bobbin-carriages stand opposite each other, of which the one is upon the front, and the other upon the back bolt bar.

We see from this diagram that, after the sixth and the tenth movements, the bobbins, although they again stand in one range upon the back bolt, have changed their places relative to each other. If we mark them once more with continuous numbers, we shall find such a change to take place during the ten movements

which are requisite for the formation of the second row of meshes. Leaving to every bobbin the number originally assigned to it, and, pursuing these metamorphoses a step further, we have the following diagram:—

		Position of the Bobbins.	
1	Movement	1 2 3 4 5 6 7 8	1st row of meshes.
6	„	1 3 2 5 4 7 6 8	
10	„	3 1 5 2 7 4 8 6	
6	„	3 5 1 7 2 8 4 6	2nd „
10	„	5 3 7 1 8 2 6 4	
6	„	5 7 3 8 1 6 2 4	3rd „
10	„	7 5 8 3 6 1 4 2	
6	„	7 8 5 6 3 4 1 2	4th „
10	„	8 7 6 5 4 3 2 1	
6	„	8 6 7 4 5 2 3 1	5th „
10	„	6 8 4 7 2 5 1 3	
6	„	6 4 8 2 7 1 5 3	6th „
10	„	4 6 2 8 1 7 3 5	
6	„	4 2 6 1 8 3 7 5	7th „
10	„	2 4 1 6 3 8 5 7	
6	„	2 1 4 3 6 5 8 7	8th „
10	„	1 2 3 4 5 6 7 8	

It is obvious that, after the completion of the fourth row of meshes, *that* bobbin which was originally the first has become the last, and the last has become the first; and that, after eight rows of meshes, every bobbin resumes its primary place. This restoration occurs, generally speaking, after as many rows of meshes as there are bobbins in the apparatus.

One of the essential peculiarities of the above-described machine is that the expanded warp-threads form a single vertical plane, and that the bobbins are usually in a single range, which is parted momentarily

into two rows only at that instant when, from the change of place in the carriages, the crossing of the weft-threads is effected. The bobbin-net machines of this nature, which otherwise differ in many particulars from each other, constitute a peculiar class. A second great division comprehends the machines with double rows of bobbins, which have this essential character, that the bobbins are always arranged in two rows, which, during the weaving, stand sometimes upon the front, and sometimes upon the back bolt, opposite to each other; but occasionally they are both upon the front bolt, and finally both are assembled upon the back bolt. In the last two cases two carriages stand behind each other in the same gate of the bolt, and the length of the bolt must be proportionally increased. In the machines with double rows of bobbins the warp is also parted into two halves, each of which extends over the whole breadth, and both are so placed that their threads lie nearly behind each other, like one warp lying over its fellow yarns in a loom. If, in the following series,

b b b b b b

a a a a a a,

a represent the threads of the front warp, and *b* those of the back warp, we shall have an idea of their arrangement, one behind another, in a horizontal section. The main advantage of the double-tier construction is, that the intervals between the double warp may be as great as in the machine with single warp; and that consequently the bolts and bobbin-carriages may be made less thin and tender. The entwining of the warp-threads by the weft-threads is effected in such a manner that every warp-thread may

be shoved, by means of a single guide-bar, both to the right and the left, in turns. Let us suppose, for example, that the bobbin-carriages have passed from the front to the rear through the warp, and that thereafter the thread, *a*, has been shogged one step to the right, or *b* one step to the left; the warp-threads will then have this arrangement,

b b b b b b

a a a a a a;

and, should the bobbins return now to the front, their threads must have been wound about the threads of the shogged warp. After the interlacement, the warp-threads will form only a single row,

a b a b a b a b a b a b,

in consequence of the reciprocal tension of the weft-threads, and the insertion of the needles of the point-bar, so as to preserve them at their proper distances.

The number of movements which are required to form a row of meshes with these double-tier machines varies according to their difference of construction. It may be done with fourteen, twelve, ten, nay even with only six, movements, when the mechanism is upon the most improved principle.

Bobbin-net lace is a thin semi-transparent web of fine cotton thread, arranged in hexagonal holes or meshes. It is produced by means of a warp, shed in two layers, as in a plain weaving-loom; only the threads are further apart. The weft, however, is applied in a very different way. It consists in an equal number of threads with the warp, which are made to revolve round every two threads of the warp, so that, after every such revolution of the weft-threads, the relative position of the two warp-threads

is changed. Among all the pairs of the warp-threads which have been just twined together by a weft-thread, one of them is shifted to the next warp-thread upon the left, and bound to it by the convolution of the weft-thread. After this the shifted warp-threads change back to their former position, when they are again laced together by the weft. Then the other threads of these pairs shift to the right, and are bound together with the remaining threads upon their right-hand side.

While this change in the position of the warp-threads is effected, the weft-threads which bind them together also progressively move to one side, so that, after the warp-threads have been laced twelve times with a weft-thread, the latter moves sideways through one interval of the warp-thread, and, if it were coloured, would produce, in the course of weaving the lace, a diagonal line across its texture. Lace-weaving, therefore, differs from common plain weaving in this, that the threads of one pair of warp are not alternately raised for the purpose of introducing the weft, but are shifted laterally to the next pair, to which they are united by the weft-threads, working likewise in pairs, each of them entwining two individual threads at a time.

The lace machine represented in plates IX. and X. is one of the most effective and improved forms which English ingenuity has created. It is called the double-bolt frame, from its double range of combs or bolts; and double-tier, from its double row of bobbins. It owes its perfect state to Mr. Morley, of Derby, to whose kindness, and that of his public-spirited partner, Mr. Boden, proprietors of the noble

lace factory of Derby, so justly celebrated in the Factory Commission Report, my readers are indebted for the present development of the lace manufacture. Mr. Morley's machine combines with the greatest possible simplicity many other valuable properties, especially that of going at very considerable speed, and producing solid and beautiful work.

Plate X., fig. 1, exhibits one of the end views of this lace-frame, which differs very little from the other end.

Plate X., fig. 2, is one-half of the front view, in which some of the framing has been left out in order to show the working apparatus behind it.

Plate IX., fig. 1, is a transverse section to display the internal operation of the machine; and in which, therefore, the driving-geer seen in Plate X. is not represented. This section is drawn upon double the scale of the other figures, to render the minute parts more distinguishable.

Plate IX., figs. 2, 3, 4, 5, 6, contain details of several parts of the machine, drawn in half of their real size.

With respect to fig. 1 of this plate, one of the end frames, A, A, of the machine, is shown; which frames are joined together upon each side by the rail, B, as seen in plate X., fig. 2.

B is an iron beam which connects together the tops of the frames, A. C is a roller upon which the warp-thread is wound, and may therefore be called the thread-beam. The length of this roller is two or three yards, according to the intended breadth of web. D is another similar roller, upon which the finished work is wound, and may therefore be called

the lace-beam. The warp-threads are extended between these two rollers in a perpendicular direction.

E is an iron bar, fixed with its ends in the frames, A, A. Round its straight edge the woven fabric is led in its way to the lace-beam, D.

F and F′ are two bars extending the whole length of the machine; on whose under edges are the guide-plates, *a* and *a′*. These have slits in their edges, through which the warp-threads are conducted in two rows up to the eyes, *b* and *b′*. These eyes are the points of needles, whose other ends are cast into pewter bars or flanges, which are screwed to the bars, F and F′. In plate IX., fig. 2, these guide-needles are shown in half their natural size.

Each guide-bar, F and F′, contains a range of these needles equal in number to one-half the number of threads in the warp: *c*, *c*, are little wooden rollers or stars, at the edges of the lace-web, furnished with sharp points, which go into the meshes of the lace as it is gradually wound upon its beam, D, in order to keep it distended.

The weft-threads which are to pass through the intervals of the warp, in order to entwine two threads of the two layers of the latter together, are wound upon elegant tiny bobbins; one of which is represented, of half its real size, in plate IX., fig. 3, in a view, *d*, and a section, *d′*. It consists of two thin brass discs, fashioned in a stamping or coining press, with a hollow in the middle of each; the two discs being rivetted together so as to leave a narrow space, or circular groove, between them, into which the thread is wound. There is a round hole in their centre, having a little notch at one point, for running them upon a

spindle-rod, with a feathered edge to fit that notch, and prevent them from turning round the rod. This spindle is put into an appropriate winding-frame, figs. 129 and 130, for filling the bobbins with thread prior to their introduction into the lace-machine.

Each of these tiny bobbins, *d*, *d′*, is inserted within a little iron frame, G, fig. 4, called the bobbin-carriage. The figure exhibits it, both in view and section, of half its true size. Into the circular hole of this carriage the bobbin is inserted, so that the groove-borders of its disc embrace the narrow edge, *e*, *e*, and are kept from falling out to the one side or the other by the pressure of a spring, *f*, which applies sufficient friction to prevent them revolving too easily, but still so little as to permit their giving out the thread when it is pulled with the very gentle force employed in the machine. The thread is led through the eye, *g*, at the top of the carriage, in order to be wound off in the formation of the lace.

The carriage G has a curvilinear groove *h*, *h*, turned out upon each of its faces or sides, the depth of which is seen in the section. These grooves fit the intervals between the teeth of the comb, or bars of the bolt, shown in plate IX., fig. 6, in which the carriages slide backwards and forwards. The carriages are driven by the impulse of a bar against one of the projecting catches or points, *i*, *i′*, which remain below the under surface of the bolt or comb.

The bobbins, with their carriages, which are equal in number to the weft-threads, have to pass through the narrow intervals between the equally numerous warp-threads. They are, with this view, arranged in

a double line, in which the intervals of the double warp are only half as numerous as the threads.

In plate IX., fig. 1, two carriages, with their enclosed bobbins, G, G, are seen upon each side of the warp-thread, and they may be supposed to be the two end ones of two horizontal ranks or lines.

H and H′ are iron bars extending the whole length of the machine, to which are fixed two lines of curved brass plates, having their ends cast into or imbedded in pewter flanges, which serve for screwing them fast to the bars, H and H′. These curved parallel plates are called bolts, though they more closely resemble combs, with very thick strong teeth. These brass plates, marked, *k*, *k′*, in fig. 1, form therefore two rows of curved channels upon each side of the warp, and are half as numerous, in each bolt, as the carriages, G, G′, which ride between them.

The free ends of the teeth or bars in the opposite bolts stand so near to each other as to leave room merely for the proper motions of the warp-threads betwixt them. Hence the carriages, in their passage across, reach the back bolts before they have entirely quitted the front ones; so that the short break or interruption in their curvilinear pathway, at the line of the warp, does not interfere with the uniformity and smoothness of their movements.

A few of these bolts are shown of half their size in fig. 6, both in ground plan and in side view. The pewter bar in which one of their ends is cast is seen in the ground plan as broken off from the rest. These are placed, as we said, upon each side of the vertical warp-threads, with a distance between their comb-like

tips of about half an inch, (*see k, k'*, fig. 1, plate IX.,) through which interval the warp-threads are stretched in parallel vertical lines. The curvature of the two bolts, taken together, forms the segment of a cylindrical surface. The two sets are placed right opposite, so that the two carriages, which always rest upon one bolt, may be shifted from the comb, *k*, to the opposite comb, *k'*, after passing through the intervals between the warp-threads.

The carriages are driven alternately from the one comb to the other by the two bars, *l* and *l'*, having their ends fixed to frames which vibrate round the centres, *m*, also the centres of curvature of the circular bolts. When, however, the driving-bar, *l* or *l'*, has pushed one of the lines of carriages nearly across the intervals of the warp, the foremost of their projecting catches or heels, *i, i*, is laid hold of by a plate, *n*, fixed upon the horizontal shaft, I, which thus pushes it quite through. Afterwards the second line of carriages, G', is driven through by the bar, *o*, also fixed upon the shaft, I, which carries them across the interval by acting against their foremost projections, *i, i*. The same thing is performed by the shaft, I', when the bar, *l'*, drives the two lines of bobbins in the opposite direction.

The beam, H, with the combs or bolts, *k'*, attached to it, can be shifted sideways a little. By this traverse motion the position of the comb, *k'*, is changed relatively to that of the comb, *k*, by one interval or tooth, so as to transfer the carriages to the next adjoining bolts. When this shifting is twice performed, the carriage, G', is led to the right, and G to the left, as will afterwards be explained.

The particular line of the warp, marked *m*, plate IX., fig. 1, is that where the meshes of the lace are made while the bobbins are moving about to entwine the warp-threads together.

L, L′, are two bars, called the point-bars, which are suspended by the arms *p*, *p*′, from the shafts, *q* and *q*′, round whose axis they vibrate. They also turn at their joints with the suspending rods, so that each of the bars may be shifted, as is shown by the dotted lines upon one of them (fig. 1).

Upon each of these bars, L and L′, pewter flanges are screwed, into which a line of pointed needles are cast, as shown at *r*, *r*, fig. 5, plate IX. The needles of both bars lie in a horizontal plane, and in the intervals of each other, when the bars are placed as shown in fig. 1, plate IX.

After the bobbins have moved several times round about the warp-threads, and entwined their threads with them, one of the point-bars, L or L′, is moved with its points from the intervals of the warp, which lies in the spaces left by the corresponding needles of both bars, and, by receiving a downward motion, falls in between the warp-threads and the weft which has been twisted round it, and carries the latter up to make another line of meshes or holes in the lace, which has, in the mean time, wound for such a length upon the roller, D. Their point-bar remains now in its place, as seen in fig. 1, and, after some time, the other point-bar makes the same motion to produce a second line of holes; which, of course, lies between the former.

To give now an idea how the warp, consisting, as we have said, of two parts, guided separately by the two guide-bars, F, F′, is entwined together by the weft

in passing gradually from the roller, C, to the roller, D, we shall suppose that both lines of bobbin-carriages, G and G′, are upon one side of the warp, and upon the bolts *k*.

1. The driving-bar, *l*, pushes the carriages, G, so as to drive the others, G′, through the intervals of both halves of the warp; which carriages are then caught by the plate, *n*, of the shaft, I, and carried completely through.

2. Now the bar, F, shifts with its part of the warp through one interval sideways, and the carriages, G, are pushed through, first, in part, by the driving-bar, *l*, and then completely by the plate, *o*, of the shaft, I.

3. The bar, F, shifts back to its former place, and the carriages, G, are pushed back by the driver, *l*′, to the bolts, *k*, and caught by the shaft, I, in the same way as before.

4. The guide-bar, F′, traverses through one interval in the opposite direction of what F did in No. 2, and the carriages, G′, are pushed through the warp by the driving-bar, *l*′, to the bolts, *k*.

5. The bar, F, shifts back to its former place, and the carriages, G′, pass through the warp again to the bolts, *k*′.

6. The bar, F, shifts as it did in No. 2, and the carriages, G, are also pushed through the warp to the bar, *k*′.

While the latter are passing the point-bar, L makes the motions above described, and carries the weft (which had been entwined round the warp by the motion of the carriages) up, to make a new line of holes.

7. The bar, F, shifts to its first place, and the bob-

bar-carriages, G, are pushed through the warp by the driver; l', to the bolts, k.

8. The bar, F′, shifts, as in No. 4, and the carriages, G′, pass through the warp to the bolts, k'.

9. The bar, F′, returns to its original place, and the carriages, G′, pass again through the warp to the bolts, k'.

10. The bar, F, shifts again as in No. 2, and the carriages, G, are pushed through the threads to the bolts, k'.

11. The bar, F′, comes to its original place, and the carriages, G, pass through the warp to come again to the bolts, k.

12. The bar, F′, shifts or traverses once more, as in No. 4, and the carriages, G′, are also pushed through the warp to the bolts, k. During the last movement, and before the guide-bar, F′, comes to stand in its original place, as it was supposed at No. 1, the other point-bar, L′, quits the holes formed round its needle-points by the point-bar, L, and, after being drawn down, falls between the warp and weft threads, and carries the interlacements of the latter up to form a new line of holes round the points of the bar, L; and now the same series of movements begins as detailed from No. 1 to No. 12.

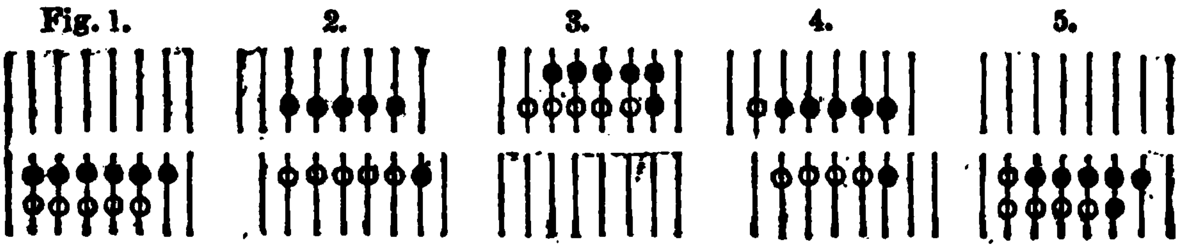
While No. 9 is performing, that is, when the carriages, G, are about to be pushed through the warp by the driving-bar, l, to the bolts, k', the bolt carrier-beam, H′, is shifted or traverses an interval of two bolts, so as to make the carriages in the line, G′, run upon the bolts which lie upon the right of those which they were formerly travelling upon.

Meanwhile, before the second line of carriages follows, as in No. 10, the beam, H′, has shifted to its former place, thus causing the carriages to come again upon the same bolts as before. Before these carriages, G, are again pushed to the bolts, *k*, the beam, H′, makes another shift or traverse like that previously made, after which the carriages, G, move to the bolts, *k*, lying to the left of those which they were travelling upon before, whilst the other line, G, after the beam, H′, has shifted to its original position, is pushed (in No. 12) to the bolts, *k*, lying to the right of those which they formerly were upon.

On the ends of the machine, however, one carriage of the line G has gone, during these movements, to the line G′, while one of these carriages, on the line G′, has gone over to the line G; so that the carriages, viewed in a body, stand as before, though the individual carriages which were opposite to one another are now working, the one at the right side, and the other at the left. This interchange will be understood by reflecting that when the carriages G′ are first pushed through to the bolts *k*′, these having been previously shifted to the left, *that* carriage which is most to the left of the line G comes after the replacement of H′ into a gate of the combs *k*′. When no carriage is in the other line, it must remain there till it is pushed by the driving-bar, *l*′, along with the carriages into the line G′. This carriage has, therefore, now changed its position from the line G to the line G′. Upon the other end of the machine a similar change is performed reciprocally. Upon this end of the machine only one carriage is working in the last gate, or between the last interval of the bolts. This

carriage, therefore, travels only when either the line G or G′ is pushed directly from the driving-bars, *l* or *l*′, but is otherwise at rest. This continues to take place till the beam, H′, shifts (traverses), and brings the line of carriages G one gate to the left, and G′ one gate to the right. The said carriage upon the right-hand side of the machine will now be shifted as the others in G, the line G′ having got two other carriages extending beyond those of the line G upon that end of the machine.

These movements will be better understood by means of the following diagram, which shows the position of the gates or bolts, , and the carriages of both lines, which are represented by the sign .



Successive Positions of Bobbins in the Gates of the Bolts.

Fig. 1. Before any change takes place with the beam H′.
2. At the operation No. 9.
3. At the operation No. 10.
4. At the operation No. 11.
5. At the following operation.

In explaining the train of mechanism in this lace-frame, the first thing is to show how the warp is gradually wound from the thread-beam, C, upon the other, or lace-beam, D.

M is a shaft, plate X., fig. 2, which is driven from the mill-shaft by a strap running over the usual fast-and-loose rigger-pulleys. From this shaft motion is

communicated by wheel-work to the other main horizontal shaft, N, which extends through the whole length of the machine.

Near the end of the machine opposite to that represented in plate X., fig. 1, a cone, O, is fixed upon the shaft N (pl. IX. fig. 1), from which another cone, P, set in the reverse direction, is driven by a strap, which may be shifted, or made to traverse from the one end to the other of the said pair of cones, to change the velocity of the shaft upon which the cone, P, is fixed.

The end of this shaft bears a worm-screw, which drives a wheel, seen in dotted lines in fig. 1, plate IX., upon the shaft O, which also bears a worm-screw, that actuates a wheel attached to the shaft upon the end of the thread-beam, C.

R is the guide of the strap fixed upon the shaft S, which is connected by an arm, and the link-rod, T, to the arm of a bell-crank lever, U, which presses with its other arm upon the thread of the beam C, and thereby, with the decreasing diameter of the beam, shifts the strap towards the larger diameter of the cone, O, and to the smaller of the cone, P, so as to increase the speed of the roller, C, as its diameter decreases, or to equalize its surface velocity, that is, the rate of delivery of the warp.

Upon the shaft, N, close to the cone, O, there is a pulley, from which another pulley, V, is driven by means of a strap. The shaft of the pulley, V, drives, by means of two bevel-wheels, the upright shaft, W, on the upper end of which is another conical pulley, X, which drives by a strap the conical pulley, Y, on an upright shaft. Upon the end of this shaft there is a worm-screw, Z, which works in a wheel, seen partly in

dotted lines, fig. 1. This wheel has upon its shaft a little pinion, which works in a wheel attached to the end of the roller, D. M′ is a lever, with a fork at its end, to guide the strap along the two cones, X and Y, and is connected by a rod, N′, with a lever, O′, which presses upon the lace wound upon the roller, D, and thereby guides the strap towards the smaller diameter of the cone, Y, and diminishes the number of revolutions of that roller as its diameter increases with the accession of lace.

Upon the shaft, N, there are likewise two eccentrics, *s*, upon each side, and one, *t*, in the middle of the machine, plate X., figs. 1 and 2, whose use will be presently described. There is, moreover, upon each end a pinion, *u*, driving the wheels, *v*, which have three times the number of teeth, and travel, therefore, with only one-third of the velocity of *u*.

Upon each of the short shafts of these two wheels, *v*, there are five eccentrics, *w*, *x*, *y*, *z*, and *z′*: *w* and *x* are upon both ends of the machine exactly the same, and consist of circular pulleys, having each one place of their circumference flattened. Upon their tops, lever arms, *c*, slide, whose fulcrum is fixed upon the framing, A, of the machine.

Other arms turning on the same fulcrum are connected by the rods, *d′*, with the arms, *e′*, fixed to the point-bars, L and L′, and may be adjusted with the arms lying upon the eccentrics, by means of screws, in order to bring the points of the two bars, L and L′, into the proper position, and into the same horizontal line. Each of these bars is therefore depressed at once, while the shaft, N, makes three turnings.

The next eccentric, *y*, upon the shaft of the wheel, *v*,

is a circular plate, with three notches at equal distances, each notch being in length about one-twelfth of the circumference. Upon an arm, *f'*, which lies upon this plate, and therefore rises and falls as it slides over the circumference, or cut-out parts of the plate, *y*, presses the bell-crank lever, *g'*, and this with its other end against the guide-bar, F, which is thus shifted at three periods during one revolution of the wheel, *v*, and shifted back as many times by a spring working against the other end of the bar, F. Upon the other end of the machine there is a similar eccentric, with this difference, that the notches in the latter stand opposite to those in the eccentric *y*. Thus it serves to shift the bar, F, likewise three times to the side, which is then pushed back as many times by a spring, *h'*, working on the end represented in fig. 1, plate X.

The eccentric, *z*, is a circular plate with two notches, comprising, with the intervals, about one-fourth part of the circumference. Upon a lever or arm which slides upon it, and is made to sink when the notches pass (*see* fig. 1), stands the rod *i'*, which is connected by a bell-crank lever, *s'*, and thus shifts the beam, H', twice during each revolution of the wheel, *v*, or during three revolutions of the shaft, N. Upon the other end of the machine there is a similar plate, having only projections of a similar shape and size to the notches in the plate, *z*, in order to bring the beam, H', back when it has been moved by the eccentric of the other end.

z is a spiral arm, which works on one or other of two studs at the ends of the two-armed lever, *t*, shown in fig. 1, pl. IX. and fig. 2, pl. X. in dotted lines only, as full lines would have covered the other parts. This

lever is suspended from the fulcrum, u'; and, being moved either the one way or the other by the arm, z', is made to press with one of the set screws, v', against one of the rods, d'; and whilst this is drawing down the point-bar, L or L′, it moves one of these bars with its points out of the holes of the lace.

w', fig. 1, pl. X. is a horizontal shaft, extending through the whole length of the machine, and having at each end an arm (represented by dotted lines,) connected by a link with the end frame of the driving-bars, l and l', fig. 2, plate X., and fig. 1, plate IX.

In the middle of the said shaft, w', there is another arm, on whose end there is a roller working in the eccentric slot of the plate, t (*see* fig 2, plate X.), by which, therefore, the carriages with their bobbins are pushed from one bolt or comb to the other, and back again, during each revolution of the shaft, N.

The eccentrics, s, upon each end of the machine, move a bar, x', up and down, the under end of which is guided by a lever, whose fulcrum is fixed to the frame-work, A, and slides with a friction-roller upon the said eccentric. The top end of each of these bars is toothed, and works in a toothed segment, y', on one end of each of the shafts I and I′; thus giving motion to the locker-bars, n and o, which draw the carriages through the warp-threads.

Bobbin-filling.

For winding the threads upon the bobbins of the lace-frame an ingenious machine is employed, by means of which from 100 to 200 bobbins may be filled at once with equal uniformity and expedition. The thread is previously wound upon a cylinder or

drum, somewhat like the parallel yarns upon a warp-beam; and from that drum the bobbins get their supply.

Fig. 129 is a side view, and fig. 130 a plan of this elegant machine. A is the drum filled with yarn in

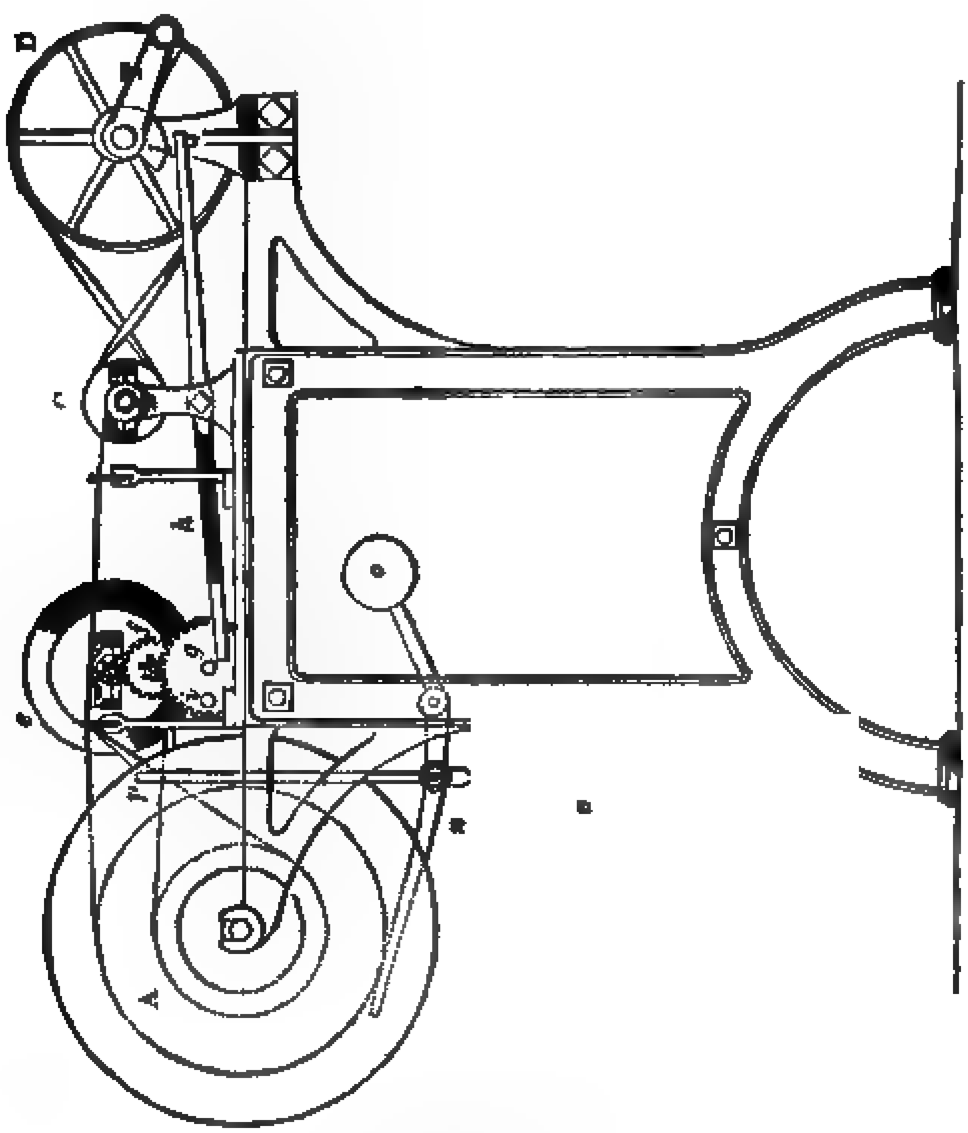


Fig. 129.—Bobbin-filling Machine. Side View.
Scale, about two inches to the foot.

parallel lines; B is a horizontal shaft, with a pulley, C, made fast to it, which is actuated by a strap from the

pulley, D. The latter is fixed upon a shaft, E, which is turned by the handle, F.

Fig. 120.—Bobbin-filling Machine. Ground Plan.
Scale, about two inches to the foot.

One end of the shaft or spindle, B, projects beyond its bearings to serve as an axle, to receive the bobbins, *a*, *a*, slid upon it close to each other; the feathered edge formerly mentioned extending along the shaft, adapted to the notch in the side of the central hole of each

bobbin, to prevent the rotation of the bobbins round the shaft.

b and *e* are two slips of brass-plate, pierced with a series of slits corresponding to the number of bobbins to be filled, and through which the threads are conducted from the drum, A, to be wound upon the bobbins by their rotation with the shaft, B. The winder, a young woman, instantly notices whenever a thread happens to break, because the train of them is led above a horizontal table, painted black. That the bobbins may be filled each time with the same quantity of thread, equal, upon an average, to 100 yards, the machine is so contrived as to throw itself out of geer, and stop, after the desired number of revolutions.

Upon the shaft of the drum, A, there is a conical pulley, *d*, from which another conical pulley, *e*, set the reverse way, is driven by a band. Upon the shaft of the latter pulley there is a pinion working in the little wheel, *f*, and thus actuating, by another pinion on its shaft, the wheel, *g*, near the circumference of which there is a stud, *i*, which, after each revolution of the wheel, *g*, depresses the lever, *h*. This, on rising, meets the catch, *l*, fixed upon the shaft, E, and stops that shaft after it has made a sufficient number of revolutions to fill the bobbins upon the spindle, B. Since the diameter of the drum, A, progressively diminishes as the threads are unwound from it, whereby it gives off less thread at each successive revolution, the speed of the little wheel must be proportionally diminished, in order to allow the successive sets of bobbins to be filled to the same degree as at first. This equation is produced by the gradual shifting of the band from the larger extremity of the cone, *d*, towards the smaller,

and of course from the smaller extremity of *e* towards the larger. The band is guided, as usual, by a forked handle, seen in dotted lines, at *p*, fig. 129. It is attached to one end of a bell-crank lever; the other end being connected by a rod, *m*, with the lever, *n*, which is pressed by a counter-weight, *o*, against the thread upon the drum, A, thus rising and shifting the fork of the strap, in proportion as the threads are unwound from the said drum.

There are several terms peculiar to the lace manufacture. The gauge, or points, means the number of gates in one inch of the bolt, or slits in the comb; and indicates, of course, the number of bobbins in an inch of the double tier. Thus, gauge nine points means nine gates in one inch of the machine.

A rack is a certain length of work counted in the diagonal direction in which bobbin-net lace is woven: it contains 240 holes or meshes. This diagonal, like that of the parallelogram of forces, in mechanics, results from the vertical motion of the warp-threads in their constant progress from the warp-beam below to the lace-beam above, combined with the transverse horizontal motion, or march and counter-march of the weft-thread along with the bobbins. Well-made lace has the meshes elongated a little in the direction of the selvage.

The common gauge used is sixteen holes in the inch, up and down the machine, for ten bobbins transversely. Circular bolt machines, represented in plates IX. and X., produce, by steam-power, fully 360 racks each per week, working 18 hours per day, with a relay of superintendents.

It is the back bolt-bar only which shogs or traverses; it moves, with its carriages, one step or gate at a time,

to the left and back again. The movements are as follows:—At the commencement the needle-points are supposed to be all in one line, and both tiers of carriages to be in the front comb or bolt.

1st *movement*. Front guide-bar shogged to the right with the front warp-threads, and the carriages are divided between the two combs or bolts, one half (about 600) in each.

2. Both tiers of carriages moved into the back comb; front guide-bar shogged to the left.

3. The carriages again parted equally between the two combs; back guide-bar shogged one step to the left, with the back warp-threads.

4. Carriages all moved into the front comb; back guide-bar to the right.

5. Carriages parted between the combs; front guide-bar to the left.

6. Carriages all into back comb; back guide-bar to the left.

7. Carriages parted; back bar to the right.

8. Carriages into front comb; front guide-bar to the right.

9. Carriages parted; front guide-bar to the left, and back comb to the left, with its tier of carriages.

10. Carriages all into the back comb; back bolt-bar to the right; guide-bar stationary.

11. Carriages parted; back comb shogged to the left, and back guide-bar also to the left.

12. Carriages all into front comb; back guide-bar to the right; back comb to the right.

The march and counter march of the bobbins, with the simultaneous movements of the warp-threads, may be rendered intelligible to every capacity by making a row of parallel slits in a couple of playing cards,

to represent the gates of the two opposite bolts or combs, into which a series of buttons may be slid by their shanks, to represent the carriages. The two cards being laid down flat upon a table, with the two sets of slits fronting each other, the following six changes of position may be made, in correspondence with those of the lace machine :—

1. Move the back comb, or card, one slit to the left.

2. Shift all the buttons upon the back card, and shove the back card one step to the right,—its primitive position.

3. Part the buttons between the two cards; an odd one will now remain upon the back card, at the left end.

4. Move the back card one slit to the left, and then bring all the buttons into the front card.

5. Move the back card one slit to the right, its original position.

6. Both sets of buttons have advanced one step to the right, and there will remain an odd one upon the right end of the front cards, while one has come from the rear to the front at the left end, indicating the commencement of the counter-march.*

Many patents have been obtained for improvements in lace machinery, which have for their object to make breadths of lace with selvages,—that is, to make such divisions in the broad sheet of net as shall allow of its being separated into distinct strips, or narrow breadths as ribands, with perfect edges.

This object had been readily effected in Lever's, and in some other constructions of lace-making machinery; particularly the circular bolt of Mr. Morley, which

* See Mr. Morley's excellent observations upon the preceding account of bobbin-net in note A, at the end of this volume.

was used for that purpose by him immediately after its first invention; and it has been likewise regularly used ever since by the trade, to whom he most liberally left it open, though it was the greatest practical improvement ever made upon the original bobbin-net apparatus. At first, Mr. Morley's locker bars had only one plate or blade, constituting the machine now called the *Single-locker Circular Bolt.* In the year 1824 he added another plate to each of the locker-bars, which was a further improvement of importance as to the machines for making plain net, though it was an obstruction to the making of breadths upon them. This machine is now distinguished from the former by the title *Double-locker.* Croft's two patents of February and December, 1832, are for a method of making breadths, upon Mr. Morley's second improvement.

I shall select an outline of Mr. Croft's first plan, as being probably more intelligible to the general reader. His second plan is undoubtedly preferable in practice, but is not so well adapted for illustrating the method of manufacturing *quillings.*

Fig. 131 represents, in partial section, the operative parts of a circular bolt machine, with double-bladed locker-bars; and in which figure the present improved parts are added. *a* shows the situation of the front range of circular bolts or combs; *b* the back range; *c* and *d* are the double tier of bobbins and carriages, in one of which ranges there must be one bobbin more in number than in the other; *e* is the front driving-bar, *f* the back driving-bar, which, by vibrating, strike against the carriages, *c*, and *d*, and cause them to slide to and fro on the circular bolts, *a* and *b*. The front

locker-bar, with its two blades, is shown at *g*, and the back locker-bar at *h*. These bars have reciprocating rotatory movements on their axes, for the purpose of causing their blades to strike against the tails of the bobbin-carriages, in order to pass them through the warp-threads in the middle.

The evolution and the mechanism for effecting these movements, and also the shogging or lateral movements of the circular bolts, are well understood as causing the threads from the bobbins to cross each other, and form the tops and bottoms of the meshes, and by twisting round the warp-threads proceeding from the roller, *i*, through the guides, *j*, *j*, to produce the sides of the meshes; the carriages being, by these means, made to move in zigzag directions, and to travel through the whole series of front combs or bolts in one direction, and of the back combs or bolts in the opposite direction.

Fig. 121.—Croft's Machine for Bobbin-net Breadths with Selvages.

If these movements of the entire ranks or tiers of bobbins and carriages were uninterrupted, the bobbins would each, as they severally arrived by their zigzag course at the ends of the ranges of bolts or combs, pass over, and return along the opposite range, forming a finish to the meshes, or a perfect selvage at each of the outer edges of the broad sheet of net, by twisting the bobbin-threads round the outer warp-threads. If, however, one of these bobbins and carriages were removed from the front range of bolts or combs, so as to leave an opening in the series of bobbins, an interruption would take place in the formation of the meshes of the net at those places where the bobbin was wanting. If single bobbins were withdrawn from the range in several places, the same interruption would take place in the formation of the connecting meshes opposite to those blanks, and the broad sheet of net would be separated at those parts into strips or ribands, technically called "*breadths,*" as the bobbins, on their severally arriving at the end of the intended breadth, would become what are called "*turn-again bobbins*"; that is, they would pass over to the opposite range of bolts or combs, and travel in the reverse direction, forming selvages round the warp-threads at those parts of the sheet of net, and, consequently, separate it into strips.

As, however, it is necessary that the several narrow strips of lace so produced should be connected together, and made to form one broad sheet, additional bobbins, as *k*, called "*whipping bobbins,*" are placed in the back combs or bolts opposite to each of these spaces, in order to be occasionally brought into operation, merely to carry a single thread round the two sel-

vages, for the purpose of whipping or lacing them together.

These whipping-bobbins, *k*, are required to be held back when the range or tier of bobbins, *d*, are driven by the bar, *f*, toward the middle; to allow of which a horizontal plate, seen edgewise at *l*, affixed to the front of the bar, has saw-gates or openings cut in it opposite to each whipping-carriage; so that when the bar, *f*, with plate, *l*, advances to drive the bobbin-carriages, *d*, the whipping-bobbins, *k*, remain stationary in the back parts of the combs or bolts; but when it is required to bring these whipping-carriages forward also, then the saw-gates or openings in the plate, *l*, are covered by a sliding piece, *m*, formed as a comb, which is attached to a bar, *n*, in front of the driving-bar, *f*, and is moved, when required, by what is termed a shogging apparatus, at the end of the machine.

The double-bladed lockers could not be made to work the ordinary bobbins, without bringing forward the whipping bobbins, *k*, with them, and entangling those carriages in the warp-threads at the time of shogging the bolts or combs: neither will a locker, with double blades, allow the turn-again carriages to remain behind when it is necessary to perform transfer; consequently such machines have not been found capable of producing broad sheets of lace divided into breadths. This difficulty is overcome by the employment of forked arms, or levers, *p*, *p*, called pickers, which are employed for pushing back the carriages of the turn-again and whipping bobbins preparatory to shogging the bolts or combs.

The series of pickers, *p*, are fixed upon horizontal bars, *q*, *q*, which turn upon pivots, hanging in bent

levers, *r*, *r*, the lower ends or longer arms of these levers being acted upon by a cam-wheel, or some other suitable contrivance, at such times as it may be necessary to raise and throw back the pickers, as shown by dotted lines.

By thus raising the picker, *p*, *p*, the turn-again, and also the whipping-carriages, are driven back in the bolts or combs, after the double-bladed locker-bars have acted upon them; and at the same time that the pickers rise up, the sliding plate, *m*, on the top of the bar, *l*, moves laterally, for the purpose of throwing open the recesses or saw-gates, into which the whipping-bobbin carriages are thereby allowed to retreat.

As soon as the outermost blade of the locker has passed clear of the teeth of the carriages, the pickers fall from their elevated position, and allow the turn-again carriage to be operated upon in the usual manner. Attached to the back locker-bar, *h*, is an extra blade, *s*, the object of which is to present itself against the tooth of the whipping-carriages after the pickers have retreated, and thereby prevent it from falling, by its own gravity, between the warp-threads at the time of shogging.

BOOK IV.

PRESENT CONDITION AND STATISTICS OF THE COTTON MANUFACTURE.

CHAPTER I.

Cotton Manufacture of the United Kingdom.

It is a truth well established at the present day, that trade tends to distribute itself in various countries in the joint ratio of their natural resources, and the industry of their inhabitants, without much regard to diplomatic considerations. Political catastrophes, such as civil and foreign wars, are accidents which may derange this distribution for awhile, but whenever they cease to act, the nations begin again to develop their peculiar faculties, and to convert them into substantial elements of prosperity. Great mistakes have long prevailed concerning the causes of the predominance of British manufactures; some having ascribed it (as the French prohibitionists still do) to our navigation laws, some to our commercial treaties, and others to our vast colonial possessions. These causes undoubtedly contributed somewhat to the encouragement of our nascent industry, but to no very great extent; and they are now nearly inoperative. It is to our coal, iron, rivers, seaports, canals, highways, capital, and the skill employed in agriculture, and the arts; or the natural resources of our peaceful island, turned to good account—that our large share in the trade of the world is to be ascribed.

The spirit of the age tends towards commercial liberty, wherever fiscal regulations allow it to follow its own course. Even the new German confederacy, however impolitic in some respects, may be regarded as the first and great measure of enfranchisement by removing custom-house trammels from its internal trade.

England has for several years adopted the liberal system; not for the purpose, as has been said, of a decoy, under which she may invade foreign markets, but in obedience to the force of circumstances. Her patent monopoly expired with the war, in consequence of the rival industry of other nations. The famous treaty of Meduen, which converted Portugal into an English colony, exists no more; free intercourse is now permitted between that country and every other; and this diplomatic event, which would have excited a great sensation in Europe fifty years ago, has passed over in our days almost unperceived, as the natural and inevitable result of the progress of opinion. Cromwell's celebrated Navigation Act has been rendered nearly non-effective by the assimilation, in many cases, of the French, American, and German shipping with the British. Even the recent ministerial inquest of France, at which the friends of free trade and the partisans of prohibition came into close conflict, shows not only the stubbornness of the tortuous roots shot forth under commercial restriction, but the barrenness of the whole protective system, and will unquestionably lead to its modification at no distant date.

In the "*Philosophy of Manufactures,*" having devoted Chapter III. of Book I. to the *Topography*

and Statistics of the factory system,—including the four great divisions of the textile manufactures,—the cotton, woollen, linen, and silk, I may refer my readers to the causes there assigned why one district is chiefly occupied with manufactures, and another with agriculture; why one selects cotton, another wool, and a third linen, as the main object of its industry.

The actual amount of the cotton manufactures of the United Kingdom has been estimated upon different principles, and with considerably different results.

From the multiplied observations which I have had occasion to make in spinning factories, I think the produce of each spindle, on an average, of mules, throstles, and self-actors, may be fairly taken at 20 hanks of the average counts of 40's. or half a pound weight of yarn, per week of 69 hours. This is 25 per cent. under the produce of Mr. Orrell's, and most of the modern mills; and 50 per cent. under that of Sharp and Roberts' self-actors. But I consider it a fair average of weight, taking into account the smaller produce of the finer spinning-mills.

The quantity of cotton delivered and used last year, ending in May 1836, for home consumption, may be fairly assumed in round numbers at 330 millions of pounds, or very nearly one million of bags, most of which exceed 300 pounds in weight. In fact, Messrs. George Holt and Co., the eminent cotton brokers, of Liverpool, in their annual statement, rate the average weight of the bags at about 335 pounds. In 300 working days, or 50 weeks of six days, 25 pounds will be spun per spindle. Hence, after de-

ducting one-tenth for waste, 300 millions divided by 25 = 12 millions, will represent the number of spindles at present at work in the United Kingdom. I believe this statement to be not far from the truth.

If we reckon each stretch of a mule to be 58 inches, and three stretches of 40's to be made in one minute, equal to 14½ feet, then 870 feet will be spun per hour; 870 yards, or a hank and 30 yards, in three hours; and nearly four hanks in the day; which amount to about 24 hanks a-week. But in the best modern mills, a stretch of from 30's to 40's weft is made in less than 20 seconds. We are, therefore, safe to assume 12 millions as the actual number of spindles in activity; since in 60's, and in still higher counts, only two stretches are made in a minute, and in counts above 140's only one stretch. In the finest numbers, a minute and a half, or even two minutes, are employed in completing a stretch.

Suppose a stretch for 120's to take one minute, then only five hanks would be spun in a week by each spindle; or 120 hanks, weighing one pound, in 24 weeks, which is very nearly half a year. At this rate no less than 150 millions of spindles would be required to spin the 330 millions * of pounds of cotton-wool last year delivered out for consumption. I have seen 170's spun at the rate of a stretch per minute; but in only one mill at Manchester, conducted by a truly scientific spinner.

Dr. Cleland, in his elaborate "*Statistics of Glasgow,*" enumerates the mule and throstle-spindles at work in Lanarkshire, in 1831; the former

* Allowing in round numbers 10 per cent. of waste.

being 591,288, the latter 48,900; which numbers are nearly as twelve to one. It is probable that the same proportion may be applicable to the whole spinning-mills of Scotland. But in those of England it will not hold, on account of the great demand for throstle-yarn for the fustian and velveteen fabrics.

It appears from the minute survey made by Mr. Crompton, in 1812, that from four to five millions of spindles were then going upon his mule principle. Mr. Kennedy estimated the number of mule-spindles in 1829, at about seven millions*. It is to be regretted that the factory inspectors had not been instructed to enrich the statistics of the cotton manufacture with a register of the numbers of mule and throstle-spindles at work in each factory under their superintendence. This information would be very valuable to the spinning trade itself, and would, I am sure, be most readily afforded by its members. It would exhibit the condition of the business more accurately than any other document, and would be peculiarly instructive in reference to the nature of children's employment. At the throstle-frames, young persons under 17 or 18 are seldom or never employed.

The quantity of cotton-wool delivered for the home consumption of Great Britain, in 1829, was 745,200 bags = 223,560,000 lbs., which is to that in 1835, in the ratio of 7 millions of spindles to 10 millions and 300,000. In 1829 the average weight of a bag is stated by Messrs. Holt at only 280 lbs.; so that the economy of package has increased since that time in the proportion of 335 to 280, or 12 parts upon 100.

* Memoir of Samuel Crompton, p. 7.

If we assume the number of mule-spindles to be to that of throstle-spindles as 8 to 1, we shall have 10½ millions of mule-spindles, and 1½ millions of throstle-spindles, as the total spinning power of the United Kingdom at the present time, March 1836.

The following estimate for 1817 was published by Mr. Kennedy, in the third volume of the "*Memoirs of the Manchester Society.*"

	Pounds.
Quantity of raw cotton consumed or converted into yarn, in Great Britain and Ireland, was	110,000,000*
Loss in spinning estimated 1½ oz. per lb.	10,312,500
Quantity of yarn produced . .	99,687,500
Number of hanks (supposing the average to be 40's to the pound) .	3,987,500,000
Number of spindles employed (each spindle being supposed to produce two hanks per day, and 300 working days in the year)	6,645,833
Number of persons employed in spinning (supposing each to produce 120 hanks per day)	110,763
Number of horses' power employed (supposing 4½ oz. of coal to produce 1 hank of No. 40, and 180 lbs. of coal per day equal to one horse's power) .	20,768

* By the official returns of the Custom-house, 124,912,968 lbs. were imported; 8,155,442 lbs. exported; and 116,757,526 lbs. retained for consumption. This year was one of great manufacturing depression. The muslin weavers were in a state little short of starvation.

Were we to adapt Mr. Kennedy's proportions to the present increased consumption of cotton wool, which is about three times the quantity then assigned by him, we should be led to estimate the spindles at 19,937,499, and the cotton-spinning operatives at 332,289,—a number far above the truth. But if we admit that *fully* three hanks of 40's are *now* spun *per diem*, instead of two, as in 1829, which, from the facts above adduced, we are well warranted to do, then the number of spindles will be reduced from Mr. Kennedy's estimate to about 12 millions, as directly deduced in my first statement. His number of spinning operatives would need to be reduced in a greater proportion than one-third. The returns of the factory inspectors last year gave the number of operatives, of all descriptions, engaged in cotton mills, as 229,382, to which, if we add 20,618, as the increase since, we shall raise their present number to 250,000. But of these undoubtedly 60,000, at least, are engaged in tending the power-looms and dressing-machines subservient to them; so that the number of operatives engaged in spinning, and in the processes preparatory to it, cannot exceed 190,000; and is more probably, about 180,000.

The cotton-mill operatives in Scotland form one-seventh of the whole number thus employed in the United Kingdom. But as much of the yarn spun in Scotland is for the muslin weavers, its average fineness is so far above 40's, as to have induced an eminent statistical writer * to regard 50's as the pro-

* John W. Cowell, Esq., in Supplementary Report of the Factory Commission, p. 119 *z*.

bable mean grist of cotton-yarns spun in the United Kingdom.

There is a remarkable document, entitled "List I. in the Tables extracted from the Returns to the Lancashire Forms of Inquiry, by Mr. S. Stanway, comprehending 151 Mills, from which complete Returns were made," according to the tabular forms issued at Manchester on the 17th and 20th of May, and 20th of June, 1833, under the direction of the Factory Commissioners. This very instructive table is reprinted in the Appendix to the first volume of this work, page 334.

The sum of average counts in the first page of the original folio table is	. .	1,697,89
" Second	. .	1,670,71
" Third	. .	1,824,00
" Fourth	. .	1,663,15
" Fifth	. .	597,68
		7,453,43.

Now if this number be divided by 149, which is the number of mills corresponding to the said sum of average counts, the quotient will be 50·0, showing that 50's are the true mean counts of English mills. Only 38 of these 149 mills are in Manchester, and many of these 38 spin low counts; so that if we take into account the finer yarns of the Scotch mills, I think there can be little doubt that the average counts of the British yarns is nearer 50's. than 40's. Were we to take 50's for the average, and were we to suppose 20 hanks to be spun by each spindle in a week of 69 hours, (which is, however, much above its productive power,) then in 50 weeks, or an average

working year, only 20 pounds would be spun by each spindle. But if we divide 300 millions of pounds by 20, the quotient, 15 millions, would in this case represent the number of spindles requisite to work up the quantity of cotton consumed last year in the factories of the United Kingdom. I conceive, therefore, that there is no exaggeration in estimating our actual number of spindles at 12 millions.

If we reckon the average weight of a piece (36 yards long) of power-loom cloth, for printing, to be 6½ lbs., and 5½ pieces to be woven upon each loom per week, then 1,000 looms will require 35,750 lbs. of yarn, which is very nearly the product of the 45,860 spindles at work in Mr. Orrell's factory. Hence from 45 to 50 spindles, spinning from 36's to 38's, are equivalent to supply one power-loom with yarn. 1,100 power-looms, with all their subsidiary spinning and dressing-machinery, require (from the data of that mill) a power of 250 horses to drive them. Allowing two horses' power for 30 looms, and one horse's power for their dressing-machine, 110 horses' power will be absorbed by 1,100 calico looms; and the remaining power of 140 horses will be expended upon the spinning and reeling apparatus of the factory. If there be 110,000 power-looms at present in activity in the United Kingdom, as is most probable, they will require fifty times their number of spindles, or 5,500,000, to supply them with yarn; and both together will require the power of 25,000 horses to impel them. The remaining 6,500,000 spindles are employed in spinning yarns for the hand-weavers, frame-work knitters, bobbin-net lace manufacturers, of this kingdom, and for exportation. Of these spindles

seven-eighths may be accounted mule, and one-eighth throstle. 500 hand-mule spindles require (including preparation) the power of one horse; and 150 throstle ones require also one horse, upon an average of the common and the Danforth construction. Hence 5,687,500 mule-spindles will require the power of 11,375 horses; and 812,500 throstle-spindles the power of 5,417 horses. Thus the total power at work in the spinning and weaving departments of the cotton manufacture would seem to be equal to that of 41,792 horses, upon the steam estimate of Mr. Watt; or more probably, on account of the great friction of the older spinning machines, 45,000.

A year ago, when the cotton manufacture was not so extensive as it is at present by about one-tenth, the number of operatives employed in its factories was, by the parliamentary returns, 229,382; it must now amount to nearly 250,000, or to about 11 individuals for the power of two horses. This proportion will, of course, be different in different mills: in some fine spinning mills there may be 10 or more individuals to a horse's power; and in coarse spinning and weaving mills, perhaps only four.

Mr. Burn, in his much esteemed "*Commercial Glance of the Cotton Trade*," estimates the average consumption of cotton wool in Great Britain, during the year 1835, at 17,750 bags weekly, and for the last week in December, 18,000 bags; which, at the rate of 342½ lbs. per bag, would be 6,165,000 lbs. "Allowing 1¾ oz. per lb. for loss by waste in spinning, the yarn produced would be 5,490,703 lbs. To spin this yarn, supposing each spindle to produce on the average 8½ oz. per week, there would be required

11,152,000 spindles. Hence it would appear, from the usual mode of calculating the capital required for cotton spinning, viz., for building, power, and machinery, at 17*s*. 6*d*. per spindle,—the capital sunk in this branch of the cotton manufacture in Great Britain amounts to £9,758,864."

From the progressive increase since the end of the year 1835, up to the present time, March 1836, we may estimate the value of the sunk capital at considerably upwards of ten millions sterling. When a power-loom factory is combined with a spinning-mill, so as to weave up the yarn produced, the sunk capital becomes more than doubled. Thus in Mr. Orrell's mill, which may be regarded as a good model establishment of this kind, if its 45,860 spindles, at 17*s*. 6*d*. each, be reckoned at £40,000, then other £44,000, at least, must be allowed for 1,100 power-looms, and their subsidiary dressing-machines, &c.

Hence 110,000 power-looms, with their appropriate spinning machinery, at the rate of £84 per loom, may be estimated at £9,240,000. The remaining 6,500,000 spindles (to make up the total 12 millions) represent a capital of £5,687,500. These two sums added together will give a total fixed capital of £14,927,500, or 15 millions sterling, engaged in the cotton factories of Great Britain, exclusive of those occupied with the bobbin-net lace manufacture.

CHAPTER II.

Statistics of the Bobbin-Net Trade.

For the following elaborate and instructive statistics of the bobbin-net trade, my readers are indebted to Mr. William Felkin, of Nottingham :—

August, 1833.

Capital employed in Spinning and Doubling the Yarn.

Fixed capital in 35 spinning and 24 doubling factories—724,000 spinning, 296,700 doubling spindles		£715,000	
Floating capital in spinners and doublers' stock, and necessary sundries		200,000	
		915,000	
Deduct 1-6th, employed for foreign bobbin-net trade		155,000	
Total capital employed in spinning and doubling for English bobbin-net trade . .			£760,000

Capital employed in Bobbin-net Making.

Fixed capital in 25 factories, principally for power machines		85,000	
Fixed capital in 1,100 power machines, averaging 11 quarters wide		170,000	
Fixed capital in 3,900 hand machines, averaging 9 quarters wide		267,000	
Floating capital in stock on hand, power owners	£150,000		
Floating capital in stock on hand, hand owners	250,000		
		400,000	
			922,000
Capital in embroidering, preparing, and stock . .			250,000
Total capital employed in the trade . . .			£1,932,000

The following Number of Hands are employed.

In spinning—adults, 4,800; children, 5,500 .	10,300	
In doubling—adults, 1,300; children, 2,000 .	3,300	
	13,600	
Deduct 1-6th employed for foreign demand .	2,300	
		11,300
In power net making—adults, 1,500; youths, 1,000; children, 500; women and girls in mending, 2,000 .		5,000
In hand-machine working—small machine owners, 1,000; journeymen and apprentices, 4,000; winders, 4,000; menders, 4,000		13,000
Mending, pearling, drawing, finishing, &c. . . .		30,000
In embroidering, at present very uncertain, probably about		100,000
Total of hands employed		159,300

Value of the Raw Material when imported, and of the Goods manufactured therefrom.

Amount of Sea Island cotton annually used, 2,387,000 lbs., value before the late advance, £179,000, but now worth £224,000. This is manufactured into yarn, weighing 1,532,000 lbs., value £766,000. But of this quantity 262,000 lbs. are sent abroad, leaving 1,270,000 lbs., value before the advance £635,000, and since the advance worth £680,000. This yarn (inclusive of about £10,000 worth of thrown silk) is worked up into

5,645,000	yards of hand lever quilling net, averaging (fine 11-point, at 1*s.* 3*d.* per square yard)	£352,815
2,207,000	yards of hand circular quilling net, averaging (fine 11-point, at 1*s.* 3*d.* per square yard)	137,935
6,622,000	yards of hand circular plain net, averaging (fine 12-point, at 1*s.* 6*d.* per square yard)	496,650
4,580,000	yards of hand rotatory plain net, averaging (common 11-point, at 1*s.* per square yard)	229,000
10,905,000	yards of power plain net, averaging (common 11-point, at 1*s.* per sq. yd.)	545,250
562,000	yards of fancy net, at 2*s.* 6*d.* . .	70,250
250,000	yards of silk net, at 1*s.* 6*d.* . .	18,750
Total sq. yds. 30,771,000	Annual produce of English bobbin-net, of the present value of . .	£1,850,650

Two years ago there was much fine yarn on hand, and many mills were then standing, or only worked three or four days a-week: all these and many others are in full occupation, their production being regularly absorbed by the actual demand; for there are now no stocks of fine yarns here or on the Continent; and while an advance has taken place in coarse yarns, equal to the rise in the price of cotton wool, none has taken place in fine yarns in this market. This state of things is not likely to continue very long; the machine owners may therefore expect an advance in fine yarns; and in that case, as it is certain that there are no stocks of plain nets on hand, it is not improbable that an advance may be obtained on that branch of our production. Either the prices of quillings must be raised, or the majority of the machines making them must stand still, under any advance of cotton yarn.

By comparing this calculation with that of 1831, when 23,400,000 square yards, the then annual produce, were worth £1,891,875, it will be seen, that while there is a difference in favour of the machine owners and workmen, in the smaller proportion of quillings to plain nets now made, and in the advantageous use of much new and improved machinery, yet, on the other hand, they are producing 7,000,000 of square yards per annum more than at that time, for about the same amount of wages and profits; the number of cotton now used being on the average as fine, and its price as high, as at the period when that calculation was made. The average fall in the price of bobbin-net has been 20 per cent.

It is probable that about £550,000, or little more than one-third of what was paid in 1831, may have been paid for English embroidery during the last twelve months. Since our statement in 1831, the embroidery put on bobbin-net, both at home and abroad, has been of a much less expensive quality than heretofore, as well as at greatly reduced wages, which will account for part of the great dimi-

nution here stated, and decreased demand explains the rest. Foreign embroidery on bobbin-net is annually on the increase, and likely to continue so.

Of late, three-fourths of our production has been exported, and chiefly in the plain state. The American trade, which has much increased, is supplied entirely in the white. Quillings are sent to the north of Europe in the white, as are also the principal part of the wide nets sent to those markets. A large quantity of wide net is sent into Belgium and into France, in the unbleached state. We have almost entirely ceased to export quillings into France, as they make an immense quantity themselves. Recently, increased impediments have been thrown in the way of the introduction of bobbin-net into France, as also of the English yarns—the latter to satisfy the French spinners, the former the makers of nets. The demand for quillings from Germany has also materially declined, and many houses are giving up dealing in the article. The extensive frauds which have been practised in putting quillings up in this market for foreign trade, both as to the lengths often being short and of inferior quality in the inside of the cards, combined with the excessive fluctuations in price, have disgusted and impoverished foreign buyers, and it is very probable may have tended to produce the present difficulty in sales.

English Bobbin-net Machinery.

Hand levers—5 and 6-quarter, 500; 7-quarter, 200; 8-quarter, 300; 10-quarter, 300; 12-quarter, 50; 16-quarter, 30; 20-quarter, 20	1,400	
Hand rotatory—10-quarter, 100; 12-quarter, 300 .	400	
Hand circular—5 and 6-quarter, 100; 7-quarter, 300; 8-quarter, 400; 9-quarter, 100; 10-quarter, 300; 12-quarter, 150	1,350	
Hand traverse, pusher, and straight bolt, averaging 5-quarter	750	
Total hand machines . .		3,900
Power, 5, 6, and 7-quarter, 90; 8-quarter, 350; 10-quarter, 280; 12-quarter, 350; 16-quarter, 30 . .		1,100
Total number of machines . . .		**5,000**

The wages paid in fine spinning are—for adults, from 8*s.* to 40*s.*, and perhaps may average 17*s.* per week; children from 2*s.* 6*d.* to 7*s.*, averaging about 5*s.* In doubling, adults from 8*s.* to 30*s.*, averaging about 12*s.*; children, from 2*s.* 6*d.* to 7*s.*, averaging about 4*s.* 6*d.*

In bobbin-net making, men, 18*s.*; apprentices, 10*s.*; boys, 5*s.* In mending, winding, threading, &c., children, 4*s.*; women, 8*s.* In embroidering, children, 1*s.* to 2*s.*; women, 3*s.* to 5*s.* per week, working twelve to fourteen hours. During the last two years an extraordinary depression has taken place in the demand, and wages paid, for embroidery, chiefly arising from competition with Belgic and Saxon embroidered goods. Wages are lower in those countries than they have been here, though our good hands were reduced to 2*s.* 6*d.* or 3*s.* a-week, for women's wages. Many have left the business in despair, and a considerable reaction has taken place, so that hands are now scarce at the rate above quoted. It is very difficult to ascertain with any exactitude the number at present employed. The health of lace embroiderers is frequently impaired, owing to their always sitting and leaning forwards over a frame when at work. Any predisposition to pulmonary disease or indigestion is brought into activity, and slight distortion of the body is common amongst them. Females are employed from a very early age, and the hours of working are much too long. The pernicious effects of this sedentary labour must inevitably be felt in future years; however, being domestic and voluntary employ, it would seem impossible to interfere.

It was observed in my former paper,* that wages were reduced in 1830 and 1831, say 25 per cent., or from 24*s.* to 18*s.* a-week; and that machines had increased in the same time 1-8th in number, or from 4,000 to 4,500, and 1-6th in capacity of production. It was also then stated to be deserving the serious notice of all proprietors of existing

* First Report of Factory Commissions, C, 1, page 186.

machines, that new ones were introducing into the trade, of such power of production as must still more than ever depreciate the value of their property, have a direct tendency to sink the small owners into journeymen, and either greatly increase the labour or depreciate the wages of the workmen. The machines that have since been built, if worked by three men, in six hour shifts, or eighteen hours per day, would each turn off 20,000 square yards of good net per annum. The result then predicted has actually occurred; the wages per rack have been much lowered, although the weekly earnings are about the same now as in 1831. The inferior machines are single-handed, aud the journeymen are working either wider or speedier machines than heretofore, so as to produce probably a fourth more net for the same wages. The verification of the then anticipated fall in the saleable value of narrow hand machines, is given by Mr. Felkin, but omitted here. It is proper to remark, that the system of bleaching by the piece still continues to exert a very prejudicial influence over the value of all machinery engaged in this trade.

This reference to the difficulties and depression of the small machine owners and journeymen, arising from home and foreign competition, naturally presents a favourable opportunity for again urging upon these classes the importance of regular weekly savings, while they have sufficient left in the price of their nets, or of their labour, to admit of putting something by that may form a fund for their future supply in the hour of need. Moderate labour and independence, they themselves will allow, are infinitely preferable to excessive exertion and poverty, and are cheaply purchased by present economy and foresight. In the absence of these principles in extensive operation, no class of persons is more open to further depression, or has greater reason to dread it. The wear and tear, both of body and mind, produced by excessive labour in bobbin-net machines,

will be found far greater than it is in a stocking-frame, or than is generally imagined. It is a fact, that diseases of the chest are even now much more prevalent than formerly amongst hand-machine workmen. The richest, most powerful, and most natural fund on which the workman or machine owner can draw, and which will enable him successfully to avert these evils, is that which he creates himself by his own savings; and enables him to command the price of his goods or his labour, not controlled by his necessities, but influenced by a prudent regard to his own welfare and that of his family.

Foreign Bobbin-net Machinery.

Calais . .	600	8-quarter 11-point hand circular, quillings: 100 of these built this year and last.	
„ . .	60	7-quarter 11-point hand levers.	
„ . .	45	various widths, old machines, pusher, traverse, &c.	
Boulogne .	30	hand circular, chiefly 8 quarter, quillings.	
St. Omers . .	30	hand machines, plain nets.	
Douay . .	145	part power, part hand machines, plain net.	
Lille . .	120	chiefly 8-quarter, 10-quarter, 12-quarter power, plain net.	
Ghent . .	35	power 12-quarter.	
St. Quentin	90	chiefly hand plain nets.	
„	60	8-quarter, 10-quarter, 12-quarter power, plain nets chiefly.	
Caen . .	35	hand quilling chiefly.	
Paris . .	10	hand machines chiefly.	
Lyons . .	50	hand machines chiefly.	
„ . .	340	scattered through the villages in the north of France, chiefly hand machines.	
Switzerland	50	nearly all hand machines.	These five states, if we may judge from their efforts to obtain model machines, are preparing to make our article very extensively.
Saxony .	70	ditto ditto	
Austria .	60	power and hand machines.	
Russia and Prussia .	20	probably, and both hand and power.	
Total	1,850	machines.	

In 1823 there were not 35 machines in Calais, and not 100 upon the Continent altogether. 3*d.* a-rack covers

labour and expenses in working 8-quarter 11-point quilling machines, at Calais; and 2*d*. a-rack covers all expenses in making 12 quarter power net, excepting the cost of the moving power. Forgers are paid on the average by machine builders 24*s*. a-week; filers, 16*s*.; setters-up, £16 for getting an 8-quarter 11-point quilling machine to work. These machines are producing about as follows:—

		sq. yds.	at	£.
220	5, 6, and 7-quarter, old machines, of various kinds, mostly plain, about 11-points . . .	330,000	1*s*. 0*d*.	16,500
100	6-quarter levers, averaging 11-points, plain . .	200,000	1*s*. 0*d*.	10,000
120	7-quarter levers, averaging 11-points, plain . .	350,000	1*s*. 0*d*.	17,500
100	8-quarter levers, averaging 11-points, half plain .	200,000	1*s*. 0*d*.	10,000
100	8-quarter levers, averaging 11-points, half quillings .	200,000	1*s*. 3*d*.	12,500
1,020	8-quarter circular, 11 points, almost all quillings .	6,124,000	1*s*. 3*d*.	382,750
290	averaging 10-quarter power, 11-points, nearly all plain	2,420,000	1*s*. 0*d*.	121,000
1,950	machines, making at present . . .	9,824,000	Square yards of net, value at English price	570,250

These machines probably use per annum, 130,000 of French spun yarn, No. 140 to 170 principally; 265,000 lbs. of English spun yarn, of which a small qu tity is of other numbers, both above and below 180, but great bulk is of that number. The value of the Eng yarn is about £140,000, or delivered in France, at £170,000.

Bobbin-net is often bleached and dressed, in France the same person, who makes one charge for both operatio say 25 centimes the *aune*, equal to about 1¾*d*. the Eng yard, for all widths.

In an able address presented to the French Chamber of Deputies, in March, this year, and drawn up by a gentleman who has been engaged during the last 35 years in the French lace trade, and who is also now a bobbin-net machine owner, it was stated, in advocating the necessity for a grant of free entry of our fine yarns, at a 20 per cent. duty, and of course a stricter prohibition of English bobbin-nets, that the price of their first machines had fallen from £600 each to £120, and, in many instances, to the price of old iron; but that there were then 1,500 good bobbin-net machines at work in France; and that bobbin-net of the value of £1,000,000 is annually used in France, of which £500,000 is of English, and £500,000 is of French manufacture.

The total result of the operations of the whole of the bobbin-net trade, during this year, may be stated as follows:—6,850 machines use 3,000,000 lbs. of raw cotton, value £225,000, which, after it has been spun and doubled into 1,665,000 lbs. of yarn, is worth £833,000. This material is worked up into 40,595,000 square yards of bobbin-net, worth, in the markets where it is produced, £2,565,000 in its plain state. It is probable that nearly 1-6th of all the plain nets made are embroidered at home, and that rather more than that quantity is embroidered abroad, enhancing the market value by £1,300,000, and making the total value £3,865,000.

The author has been induced to bestow the requisite time and labour upon the compilation of the remaining part of this statement, from the conviction, that the more light is thrown upon this, as well as every other branch of business, the more cautiously and safely will capital be introduced into it, and the less risk will there be of those excessive fluctuations which we have often experienced in the value of machinery; and in the proportion between demand and supply, as well as, in the end, of the working classes suffering by unnecessary depression in their wages. Nothing

has more tended to overload this trade with machinery, depress wages, and destroy profits and capital, than the extraordinary elevations and depressions in prices of bobbin-net, and which may generally be traced to ignorance on the part of both buyer and seller as to how high or how low sales may be forced in this market. The experience of no former period has exhibited this feature in our trade more clearly than that of the past year.

During this interval we have had a rise in many articles of 25 per cent. without any extraordinary demand, and a fall of 30 per cent. on the average of the whole production, without any superabundant supply. Machines are far less valuable than ever before; a more than usual amount of new ones have been constructed, and are now in process of construction; and the prices of bobbin-net have been lower than at any previous epoch of the trade.

Mr. Felkin has published a table, which gives as accurate an account of the public sales of machinery, during the last nine years, as his sources of information would allow; and as he has bestowed some pains to render it tolerably complete, it will probably be found sufficiently accurate to justify, when combined with the account he has obtained of the prices for which the majority of the machines were sold, the rate of depreciation stated to have recently occurred in the value of the great bulk of machinery now in the trade. In reference to this and all other similar calculations, any pretension to absolute accuracy is of course disclaimed: the correctness of general deductions, in these cases, depends upon the bearing of the sum total of the facts adduced, and not upon any minute particulars.

A list of hosiery and other frames, sold during the same period, is also given by him, as likely to prove interesting on grounds independent of the principal inquiry.

In the year 1824, and the spring of 1825, speculation in machinery prevailed to such an extent, that levers sold for

£90, circular for £80, and pusher and traverse warps for £50 to £70 per quarter of machine in width. But in the subsequent depression, during the first six months of 1826, levers fell to £18 to £20 a-quarter; circulars, to £15 to £18; and pushers and traverse warps, to £10 to £15. From January to March the working hours were restricted to 12, 10, and 8 per day. Bobbin-net improved in price in 1827, and again fell in 1828; in November of which year a restriction commenced, which continued for 12 months, limiting the time of work to about 12 hours a-day. In the latter end of 1828, levers machines sold for £12, circulars for £15, traverse warps for £3 to £4, and pushers for £6 each per quarter. In 1828-9, 535 machines appear to have been publicly offered for sale; in 1830-1, 206 only were offered. In 1828, many machines were built, but few in 1829, and more in 1830, chiefly 8-quarter and rotary. In 1831 many 10-quarter hand rotaries were built. The prices of bobbin-net rallied in 1829, and continued tolerably steady through 1830 and part of 1831. Towards the end of 1831 they fell materially. In the spring of 1832 some articles attained an unnatural height as compared with others, and in the autumn prices began to give way generally. They seem to have reached their lowest point for the present about Christmas, 1832, having then been sold, in many cases, under prime cost; for the rise which has taken place in cotton yarn, (in itself a singular circumstance, while many machines are making less work,) to be accounted for in good part by increased foreign demand, has been more than equivalent to the reduction to which the workmen have unhappily been compelled to submit. Levers machines will now only bring, when offered for sale, about £4 to £6 a-quarter in 6-quarter to 8-quarter, and circulars are nearly the like value. Eight circular machines, averaging 8-quarter 11-point, and which cost the parties, in 1825, £5,000, were sold lately for £300. Pushers, which were sold temporarily

in 1829 for £20 to £25 a-quarter, will not now realize more than £3 to £4 a-quarter; and traverse warps are sold for £2 or £3 a machine. Rotary machines, when brought into the market, sell for £12 to £15 a-quarter, 8-quarter to 12-quarter wide. Setting the private sales, which are continual, and often considerable, against such part of the above amount of 1,843 machines publicly offered, as may have consisted of re-sold machines, and which would far more than make up the difference, it would result that, since the panic of 1825-6, one-third of all the machinery in the trade has passed out of the hands of the original owners. In the year 1832 there appear to have been only 213 machines brought into the market; but many more have exchanged owners through being mortgaged and taken possession of by creditors; and still more would have been offered of the inferior kinds, but from a conviction of the impossibility of realizing anything approaching to their supposed intrinsic value. Many such machines are single handed, or not worked at all. Where worked, the produce is selling at so low a rate, as to leave scarcely any thing beyond the price of the cotton.

It has been stated that the depreciation has been mainly upon the hand machines, up to nine quarter in width. It was calculated, two years ago, that there were 3,500 hand machines of all widths in the trade; the then current market value (not cost or maker's actual price) was about £390,000. The extreme present market value of them would be probably nearly as follows, viz.:—

1,350 levers	£71,500	Total £185,000; leaving a difference, compared with their value in September 1831, of £205,000, or more than one half.
100 rotary	£16,500	
1,300 circulars	£86,500	
750 pushers, traverse warps,	£10,500	

And this loss must fall, if no re-action take place, upon the present holders of these machines. The improbability of

any such permanent improvement in the demand for bobbin-net, compared with the supply, as would materially raise the selling-price of these machines, or their working value, will appear from the fact, that during the last two years there have been built in this country, for home employment, about 300, 10 and 12-quarter hand rotary; 100 power, 12-quarter chiefly; 50, 12-quarter hand circulars; and 50 levers, 12 to 20-quarters; making an increase, since 1831, of 500 machines, averaging 12 quarters in width, of great speed and excellent construction. The outlay of English capital, in new bobbin-net machinery, in 1832 and 1833, has been at least £100,000. During the same time, it is probable that 200 new machines have been got to work abroad which cost £40,000. If my information be correct, not only many machines are building for the English trade, but capital is flowing even more rapidly into the foreign manufacture. The very extensive export of models, working drawings, and every part composing the insides of machines,—such as bolts, bobbins, carriages, points, &c.,—is strongly corroborative of this important fact.

W. FELKIN.

Nottingham.

Bobbin-net Frames in 1835.

Nottingham	582	
Rest of county	1,538	
		2,120
Leicestershire		385
Derbyshire		282
Mansfield and Chesterfield		132
West of England and Isle of Wight		793
		3,712
At stand		165
At work		3,547

Hands employed, 5,868; Power Factories, 29 or 30; Hand Factories, probably 40.

Goods produced, and Value and Number of each kind of Machine.

	Square Yards.	£.	Machines.
By Rotary Frames . .	15,827,848 . .	662,255 . .	1,585
Lever „ . .	8,327,240 . .	476,959 . .	1,225
Circular „ . .	2,627,137 . .	141,864 . .	420
Pusher (Grecian) .	811,650 . .	41,574 . .	165
Traverse Warp . .	325,188 . .	54,198 . .	152
	27,919,063	£1,376,850	3,547

Machines employed in making	Plain Net . .	1,425	
„ „	Quillings . .	1,122	
„ „	Fancys	998	
		3,545	(an error of 2 somewhere.)

Width of Net produced by Machines.

4-Quarter	8	11-Quarter	172
5 „	51	12 „	816
6 „	366	13 „	29
7 „	262	14 „	9
8 „	1,084	15 „	3
9 „	168	16 „	31
10 „	546	20 „	2
	2,485		1,062
			2,485
			3,547

271,000	lbs. yarn, No. 130 to 170, inclusive.	
350,000	„ „	180
250,000	„ „	190
220,000	„ „	200
60,000	„ „	210
9,000	„ „	220
1,160,000	*Net* value, £604,616.	

640,000	used in	Nottinghamshire,
100,000	„	Leicestershire,
100,000	„	Derbyshire,
320,000	„	West of England.
1,160,000		

The last tabular statement was recently drawn up by Mr. Felkin, with his usual zeal, at the request of the Board of Trade, and through the favour of Mr. Porter it is here laid before my readers.

We shall conclude these general statistics of our cotton manufactures with a sketch of the topography of its various fabrics.

The chief seats of our muslin manufacture are Paisley, Glasgow, and Bolton; each place producing an article in some respects peculiar. The variety called jaconets, both coarse and fine, but always stout, as well as checked and striped muslins, and other articles of the heavier sort, are made in Bolton and its neighbourhood. Book muslins, as also those called mull and line, of lighter fabric than the Lancashire, are made at Glasgow. Paisley is celebrated for its sewed and tamboured muslins, which give domestic employment to great numbers of young women in the West of Scotland. Mechanical tambouring was attempted nearly thirty years ago at Glasgow, by means of a most ingenious machine invented by Mr. John Duncan, but it has never been found so profitable as to be pushed to any considerable extent, owing to the abundance and dexterity of the hand tambourers.

Figured muslins, called fancy goods, were first woven in the loom at Paisley, which having been previously the chief seat of the silk gauze manufacture, had trained a race of most ingenious artisans, distinguished for a spirit of study and research which would have done honour to men in the most exalted stations. They immediately transferred to cottons the elegant

patterns which they had been accustomed to give to silks, and thus rendered their native town for many years the sole possessor of this beautiful branch of the trade. And even at the present day, though many of the principal manufacturers of Paisley have removed their warehouses to the more general emporium of Glasgow, yet they continue to draw their supply of goods from their former townsmen. This fact, joined to the circumstance of the fine muslin yarn being chiefly brought from Manchester to Paisley, shows how a manufacture, which depends on the skill of a colony of workmen, gets fixed and rooted, as it were, among them, in spite of many motives and efforts to transplant it. Thus also the Manchester spinners o fhigh numbers have never been rivalled by those of Glasgow, whatever pains the proprietors of the mills in the latter place may have bestowed in getting their machines made in the best manner, and after the most improved patterns.

The thicker cotton goods have also their favourite localities. Dimities continue to be exclusively manufactured in the North of England, though they have been often attempted, but in vain, by the Scotch. The finer qualities of these goods are made at Warrington, the coarser in the West Riding of Yorkshire. Preston and Chorley still retain Balasore handkerchiefs to themselves. Ginghams, however, which were long monopolized by Lancashire, have for several years been partially extended to Glasgow. On the other hand, Pullicat handkerchiefs—a style of goods first introduced at Glasgow in 1785, and manufactured exclusively there to a great extent for many years—were eventually introduced into Lancashire,

but have never attained the same magnitude as in their birth-place.

Blue and white checks and stripes for the tropical markets are woven chiefly at Carlisle; though some are also made in Lancashire, and the county of Fife.

The manufacture of cotton cambric sprung up also from the mule-frame, and became characterized by two styles,—cambric for ladies' robes, either white or printed, and cambric resembling the fine linen cambric of France, for which it was designed to be a substitute: Lancashire is the sole seat of the first style, which it fabricates to an immense amount; Glasgow is the seat of the second style, and which is of much more limited demand. Either place has endeavoured, but in vain, to compete with its rival in this analogous production.

Effects of Improvements in Machinery upon the Prices of Products.

In the year 1782, Arkwright's cotton twist of No. 60 exceeded the price of the raw material by 20*s*. a lb., or, in other words, he charged 1*l*. sterling for spinning one pound weight of cotton into such yarn. In 1830 the charge for spinning one pound of such cotton yarn by the mule was only 1*s*. 6*d*. If we take into account the depreciation of the value of money since 1782, the decrease will be from 20*s*. down to 9*d*., that is in the proportion nearly of 27 to 1.

The number of mule-spindles going in 1812, appeared by actual survey to be 4,200,000, producing a quantity of cotton yarn equal at least to what could be spun in the same time by 4,200,000 persons working diligently with our household wheel.

In Great Britain all these spindles were conducted by 70,000 persons, working at average wages of 20*d.* a-day each; being one-sixtieth the number of persons necessary to manage as many spindles in India. But on account of more expensive apparatus and various contingencies, let us assume the ratio of 40 to 1. Then 40 Indian spinners at 2*d.* a-day, receiving altogether 6*s.* 8*d.*, will produce no more yarn than one British spinner at 1*s.* 8*d.*, being one-fourth of the wages. If we take into account also how many yards of good calico one person will turn off by a power-loom in the time that the Indian tanty would turn off only one, we may well understand how the cotton fabrics of Great Britain may eventually clothe not only her subjects in Hindostan, but the immense population of Eastern Asia, and its multitudinous isles.

The progressive fall in the prices of cotton yarns during the short space of 18 years is exhibited in the following Table, presented by John Kennedy, Esq., of Manchester, to a Committee of Parliament in 1830.

Hanks per day per spindle.			Price of Cotton and waste per lb.		Labour per pound, average 20*d.* per day, in		Cost per pound.	
Description of Yarn.	1812.	1830.	1812.	1830.	1812.	1830.	1812.	1830.
No.			*s.* *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*
40	2.	2.75	1 6	0 7	1 0	0 7½	2 6	1 2½
60	1.5	2.5	2 0	0 10	1 6	1 0½	3 6	1 10½
80	1.5	2.0	2 2	0 11¼	2 2	1 7½	4 4	2 6¾
100	1.4	1.8	2 4	1 1¾	2 10	2 2½	5 2	3 4¾
120	1.25	1.65	2 6	1 4	3 6	2 8	6 0	4 0
150	1.00	1.33	2 10	1 8	6 6	4 11	9 4	6 7
200	0.75	0.9	3 4	3 0	16 8	11 6	20 0	14 6
250	0.05	0.06	4 0	3 8	31 0	24 6	35 0	28 2

Indian prices remained the same at both periods.

Prices of Cotton Yarns per Hank.

English Prices.			Indian Prices.
	1812.	1830.	1812 and 1830.
No.	*d.*	*d.*	*d.*
40	1½	0¾	2⅛
60	1⅜	0¾	2⅜
80	1 5/16	0¾	2¼
100	1¼	0 13/16	3
120	1 3/16	0 13/16	3¼
150	1⅛	1	4 1/16
200	2⅜	1¼	5⅜
250	3⅝	2¼	8

"It is upon the basis of spinning that the great abridgments of labour, and the consequent cheapness of the cotton manufacture, have been chiefly founded, and by which this country will be able to meet competition in the eastern markets, either in yarns or in cloth, of which they form the principal constituent value. Very important discoveries and improvements have doubtless been made in weaving, dyeing, printing, and bleaching, and particularly for certain operations and descriptions of cloth; but, taken in the gross, the amount will bear but an inferior proportion to the economy introduced by spinning, upon which both invention and exertion have been upon the rack for the last 30 years, and a real capital vested in building and machinery of 10,000,000*l.* sterling. The consequence of these improvements has been, that by the last returns, from 4,000,000 to 5,000,000 lbs. of cotton yarn have been exported to India in one year, while in 1812 only a few samples were sent."*

* Mr. Kennedy *ut supra.*

The fall of price is much more remarkable with regard to calicoes than to yarns. Of this fact Mr. Everett has afforded striking evidence in the following statement of cotton goods which he shipped in American traders from England to Canton during the years 1820-1, and down to 1828 inclusive. The total quantity was 226,571 pieces, value £207,784.

Depreciation of the Cost of Cotton Long Cloths since 1820.

1821	from 2½	to 5	per cent.	1826	from 30	to 35	per cent.
1822	5	7½		1827	35	40	
1823	10	15		1828	40	45	
1824	20	25		1829	45	50	
1825	12½	15		1830	47½	50*	

Thus nearly a double quantity of long cloths might be bought in 1830 for the same money as in 1820; and thus a double number of persons might be enabled to purchase and wear them.

By the increased exports of our manufactures, as their prices fall, we are enabled to obtain a vastly greater proportion of the productions of foreign nations than we did 20 years ago, as the following statement of *imports* at two such intervals will show:—

				1810.		Home Consumption. Jan. 1836.
Sheep's wool		lbs.		10,914,137		43,185,993
Cotton wool {home consumption.}		do.		90,000,000		333,000,000
Sugar	do.	cwts.		3,489,312†		4,466,000
Coffee	do.	lbs.		5,308,096		22,326,000
Wine	do.	galls.	in whole	6,805,276	in whole	6,640,519 9,033,000
Tea	do.	lbs.	do.	22,000,000	do.	36,606,000 41,194,000
Pepper	do.	do.	do.	1,117,000		3,345,000

* Commons' Report on Indian Affairs, 1830.

† A great deal was consumed in the distilleries this year.

Prices of Upland Georgian Cotton Water-twist, No. 20, *⅞ Shirtings, and ¾ Velveteens.*

Years.	Cotton.	Water Twist.		⅞ Shirtings per piece.				¾ Velveteens per lb.	
			Diff. to Cotton.			Diff. to Cotton.			Diff. to Cotton.
	d.	*d.*	*d.*	*s.*	*d.*	*s.*	*d.*	*d.*	*d.*
1827	6½	12	5½	.	.	.	.	.	.
1828	6⅜	11⅛	4¾	.	.	.	.	21⅞	15½
1829	5⅞	11⅛	5¼	.	.	.	.	18½	12⅝
1830	6⅞	11½	4⅝	13	5	7	4½	18⅞	12
1831	5⅞	10⅝	4¾	13	0	7	10½	19¼	13⅜
1832	6⅝	10⅞	4¼	13	0	7	2½	17⅝	11
1833	7⅝	11⅜	3¾	13	1	6	4	17⅛	9½

The loss of cotton of that quality in waste amounted to one-eighth, or 2 oz. per lb. The above Table was given in to the Committee on Manufactures by Joshua Milne, Esq., of Crompton, near Oldham. He has four mills, employs about 770 hands, several of whom are in families earning from 40*s*. to 50*s*. per week, and has lately disposed of power-looms for £255, which cost him £1,400, and replaced them by others of an improved construction. In his manufacture he allows 5 per cent. for interest of money, and 10 per cent. annually expended on repairs of the machinery, but 33 per cent. on the cards, which must be renewed every three years. He admits, that as he is working more cheaply now than formerly, in consequence of improved machinery, the difference between the price of raw and manufactured cotton is not a correct criterion of his rate of profit. The new looms cost only £800, and did better work than the old, which cost £1,400. This is a particular case, and could not be applied to the rest of the apparatus in the mill. The old looms were for fustians, and had been

originally ill constructed for their work. "There is some machinery," adds he, "which it is better to burn than to use."*

Table of the Average Price of Cotton compared with Twist Sold.

The column "Difference" may be considered as denoting the progress of machinery in the cotton manufacture during the last thirty years. As the first number in this column is 20·2*d.*, and the last 5·37*d.*, it would seem to follow that cotton-spinning machinery is now nearly four times as efficient as it was thirty years ago. This conclusion is not, however, quite accurate, at least for the numbers given since 1825; as, from that period, the prices of yarn have been frequently insufficient to pay the cost of production, owing to the universal introduction of power-looms. This paradoxical result has been brought about in the following way:—Previous to the general use of power-looms, hand-loom weavers were the principal purchasers of cotton-yarn; but when the power-loom was extensively introduced, the manufacturing of cloth, by its assistance, did not form a separate business, as in the hand-loom trade, but was carried on under the same roof with the spinning of cotton, the manufacturers of yarn having added a power-loom department to that of their spinning machinery. The hand-loom weavers could not, of course, work against the competition of the steam-looms, or if they did struggle to earn a scanty subsistence from their business, they could do so only by giving a far lower price for the yarn they made use of than before; the consequence was, that there were

* Supp. Report Factory Commiss. p. 185.

hardly any buyers of yarn in the market, and the price was reduced so low that the profits of the spinners of it were almost annihilated; many of them were brought to bankruptcy, and, of late years, those coarse cotton-spinners only have driven a profitable trade, who have annexed power-looms to their spinning establishments. This explanation is necessary in reference to the present Table. The factory to which it refers is solely for spinning. This does not prove that the cotton business in general has been profitless for the last few years, but simply that the mode of conducting it profitably has changed, and that those who have stuck to the old method of proceeding have suffered severely.

At this moment (May 1836) the demand for yarn in the foreign (chiefly German and Russian) markets is so brisk, as to render power-weaving an unprofitable business relatively to spinning. Such are the vicissitudes of trade!

Average Price of Cotton compared with Twist Sold.

—	Cotton per lb.	Twist sold per lb.	Average Number.	Difference.
From December 1804 to December 1805	19.6	39.8	25.9	20 2
— — 1805 — — 1806	19.09	26 10	25.	17 1
— — 1806 — — 1807	21.54	36.70	25.78	15 16
— — 1807 — — 1808	24.83	[illegible]	24.61	13 [illegible]
— — 1808 — — 1809	26.83	41.91	24.37	15.09
— July 1809 — — 1809	20 73	37.01	24.60	16.28
— December 1809 — July 1810	20.93	40 79	22.97	19.86
— July 1810 — December 1810	19 76	38.51	22.96	18.76
— December 1810 — July 1811	17.96	34.40	23.09	16.44
— July 1811 — December 1811	17.43	28 71	20.69	11.28
— December 1811 — July 1812	17.81	29.72	23.15	11 91
— July 1812 — December 1812	18 24	29.09	24.46	10.85
— December 1812 — July 1813	24.75	35.46	25.27	10.71
— July 1813 — December 1813	25 19	35.08	25.62	9.96
— December 1813 — July 1814	33.52	46.92	25 06	13.40
— July 1814 — December 1814	31.47	[illegible]	[illegible].	13.78
— December 1814 — July 1815	25.72	37.40	22.65	11.78
— July 1815 — December 1815	26.53	38.44	25.	11 91
— December 1815 — July 1816	20.47	37.74	25.4	17.27
— July 1816 — December 1816	20.74	33.8	25.3	13.07
— December 1816 — July 1817	22.8	34.65	[illegible].7	12.25
— July 1817 — December 1817	20.44	[illegible]	26.46	13.16
— December 1817 — July 1818	[illegible]	34.55	26.6	14.00
— July 1818 — December 1818	21.12	32.95	[illegible].4	11.83
— December 1818 — July 1819	14.49	30.83	24.63	16.36
— July 1819 — December 1819	13.65	27 53	24.95	13.88
— December 1819 — July 1820	14.44	26.03	25.70	11.59
— July 1820 — December 1820	11 62	21.40	25.18	9 78
— December 1820 — July 1821	9.89	20.11	25.73	10.22
— July 1821 — December 1821	[illegible]	19.45	25.83	9.54
— December 1821 — July 1822	9.22	19.27	23.54	10.04
— July 1822 — December 1822	8.34	19.14	25.6	10.8
— December 1822 — July 1823	7.8	19.23	25.6	11.43
— July 1823 — December 1823	8.24	19.63	25.34	11.39
— December 1823 — July 1824	8.81	19.41	25.9	10.6
— July 1824 — December 1824	8.78	19.09	26.1	10.31
— December 1824 — July 1825	14.	23.34	26.2	9.36
— July 1825 — December 1825	13.06	19.11	29.1	6.05
— December 1825 — July 1826	7.6	16 5	27.78	8.9
— July 1826 — December 1826	[illegible]	15.17	30.	8.25
— December 1826 — July 1827	6.95	14.97	30.96	8.02
— July 1827 — December 1827	7.34	14.77	30.	7.43
— December 1827 — July 1828	6.26	13.	27.41	6.74
— July 1828 — December 1828	6.64	13.3	28.24	6 66
— December 1828 — July 1829	6.23	12.96	28.23	6 73
— July 1829 — December 1829	6.34	13.43	29.00	7.09
— December 1829 — July 1830	7.01	13.23	27.85	6.27
— July 1830 — December 1830	6.82	12.72	26.77	5.90
— December 1830 — July 1831	6.65	12.82	28.58	6 17
— July 1831 — December 1831	6.62	12.37	27.40	5.55
— December 1831 — July 1832	6.97	12.76	29.42	5.[illegible]
— July 1832 — December 1832	7.34	12.61	29.62	5.27

Furnished by Samuel Greg and Co., not from their own mills, but they can vouch for its being accurate.

PRICES of MANCHESTER COTTON TWIST, abridged from Mr. W. F. REUSS's excellent TABULAR VIEW of the COTTON MANUFACTURE of GREAT BRITAIN.

	1828.		1829.		1830.		1831.		1832.		1833.		1834.		1835.	
	Jan.	July.	Jan.	July.	Jan.	July.	Jan.	July.	Jan.	July.	Jan.	July.	Jan.	July.	Jan.	July.
	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*	per lb. *d.*
Mule No. 20, Best Second	. .	. .	. .	. .	10¾	. .	11	10½	10⅛	10½	11¼	14½	12¼	14	14	15¼
No. 40, Ordinary	11½	13	12¾	12½	12½	12¾	11⅜	11	11⅛	11¾	12¼	14¾	12½	15	15	17
Good Second	12	13¼	13	12⅞	12¾	13¼	12½	11¼	12	12¼	12¼	15	13	15	15¼	17⅛
Best Ditto	12½	14	13½	13¼	13¼	13¾	13	11¾	12½	13	13	15⅜	13½	15⅛	15¾	18
Extra Best Ditto	14	14½	14¼	14¼	14	14½	14¼	13	13¾	14	14	16¼	14¼	16½	17	19¼
No. 50, Ordinary	14	15¼	14¾	14¼	14½	15¼	14¼	12¼	13½	13¼	13½	16½	14½	16¾	16½	19
Good Second	14¾	15¼	15	14⅝	14⅝	15½	14¾	12½	13¾	13¾	13¾	16¼	14¾	17	16¾	19¼
Extra Best Ditto	16½	17	16	16¼	15⅝	16¼	16	14¼	15½	15½	15¼	18½	17	18¾	20¼	22½
No. 60, Good Second	16½	17½	17¼	16¾	16¼	17¼	17	14¼	15¼	15½	15¾	18½	17¾	20	19	22¼
Best Ditto	17	18	18¼	17¼	17¼	17¾	17¼	16	16¼	16	16	19	18¼	20	19¾	22¾
Extra Best Ditto	18½	19	19¼	19½	19¼	19¾	19¼	19	19	19	18¾	22¾	20½	23	24	26
Prima	23½	23½	22½	21½	22	22	22	21	20½	20½	20½	23½	22	25¼	27¼	27¾
Water Twist, No. 20, Ordinary	9¾	10¼	10½	10½	10¼	11	10¼	9	10	9¾	10	12½	11	13½	13½	14
Good Second	10	10¾	10¾	10¼	10½	11¼	10¾	9½	10¼	10¼	10⅛	14¼	12	13¾	14	15
Best Ditto	10½	11	10⅞	10⅞	10⅝	11½	11¼	9½	10¼	10½	11	14	12¼	14¼	14¾	15⅜
Extra Best Ditto	. .	11¾	11	11¼	11	11½	11⅞	10	11	11	11	14¼	12¼	14¼	15	16
No. 30, Ordinary	12	12¼	12¾	12¾	12¾	12¾	11¼	10½	11½	11¾	11¾	14⅛	12½	15	15¼	16½
Good Second	12¼	12¼	13	13¼	12⅞	13¼	12¾	10¾	12	12	12¼	15	13	15¼	15¾	18
Best Ditto	12½	13¼	13¼	13½	13¾	14	13	11½	12¾	12¼	12½	15⅛	13½	15½	16¼	18¼
Extra Best Ditto	15½	14¾	13¾	14	14⅛	14½	14¼	13	13¾	13¼	13¼	16	14¾	16¼	17½	19¾
No. 40, Good Second	16½	16½	16	16	16	16¾	16¼	14½	15	16	15¾	. .	18	19	20	23
Best Ditto	17½	18	17½	17½	18	18½	17¼	16	16¾	17	17	19¼	18¾	19¼	21	24
Extra Best Ditto	19	19	18½	18¼	18¼	18½	17½	16¾	17¾	17¼	17½	19¼	19	20	21⅜	24¾
Medio, No 50	16	16½	16	16	16	17	16½	15½	16	16¼	16½	18	16½	18¼	19¾	22¼
,, 40	18½	19	19	18	17	18	17	15½	16½	16½	18	20½	. .	. .	24½	28¼

1828. The demand for yarn at the beginning of this year promised to be favourable, but, from the multiplication of power-looms, the price of calico fell, generally speaking, so low as to afford little remuneration to the manufacturers. In the last months of the year particularly, from the diminished vent, it became lower than at any former period.

1829. The depression which prevailed at the conclusion of last year in the cotton cloth trade continued, without interruption, during the first six months of the present year. Considerable bankruptcies occurred, which, in conjunction with the disputes which arose between the mill-owners and the operatives about wages, occasioned a long suspension of the course of business. The cotton twist trade, however, was far from being unsatisfactory as to price.

1830. The influence of the Belgian revolution on the commercial world, as well as the differences revived towards the end of this year between the manufacturers and their workmen, obstructed not a little the demand for all sorts of cotton goods. The trade, however, indicated a steady tendency to increase, especially at the beginning of the year; but towards its close the purchasers were seized with a panic on account of the unsettled state of Continental politics.

1831. The demand of cotton yarn and fabrics for exportation was upon the increase at fair prices. These became unfavourably affected in December by the new Act of Parliament for restricting the hours of labour in factories, to which circumstance some of the manufacturers fell a sacrifice.

1832. The business of the factory districts being no longer disturbed by trades' unions, strikes, and quar-

rels, the manufacture of cotton in all its branches advanced in a constant and satisfactory manner; the export of twist, in particular, was greatly increased, although complaints were made by the mill-owners of the little difference in price between the raw and manufactured article.

1833. This year is the commencement of a new era in the trade of England, in consequence of the Slave Emancipation Act, the new Bank Charter, and the opening up of the trade to China. These important measures, dictated by the liberal spirit of the age, soon began to display their propitious influence in every department of British industry. Their primary effect was to excite extensive speculations in cotton wool and cotton yarn.

1834. The beneficial influence of the philanthropic acts of the British Parliament in 1833 upon the prosperity of the country were very conspicuous in 1834, especially in reference to the textile manufactures. The fabrication of cotton goods became not only more extensive, but assumed a more substantial and healthful character. All the hands were in full employment during the course of the year. As the prices of cotton wool remained steady during the first nine months, the spinner derived the full advantage of the improved demand for his goods. The factory operatives now ceased to complain either of low wages or of the hours of work, having full occupation, with bread and other necessaries of life at moderate rates, in spite of the corn laws. Commercial enterprise gave itself up the more confidently to the allurement of the times, as no interruption to its success had lately occurred.

1835. The increased facilities of trade, and the

large demand for cotton twist in the China market, the extent of which is yet unknown, along with the quickly-advancing consumption of the old customers in every country, the continuance of peace, and the soundness of credit, gave to the cotton trade of Great Britain this year a prodigious impulse. The anticipation of a very large demand exciting fears of a short supply of the raw material caused a panic in the cotton-wool market, which reacted upon the yarns, and raised their prices towards the conclusion of the spring months, without the aid of speculation. At the end of the month of May, Georgia and Louisiana cotton wools stood 2*d.*, Sea Island and Egyptian 3½*d.* to 4*d.*, and Brazil 3*d.* higher than in January, cotton twist rising in a similar proportion. The alarms of the trade were by this time appeased, and the fears of a short supply of cotton wool seemed to be unfounded.

According to Mr. W. F. Reuss, the production of cotton yarn in Great Britain, in the year 1835, was as follows:—

	lbs.
Cotton wool spun	315,997,442
Waste in spinning	34,562,220
Total yarn made in England and Scotland	281,435,222
Scotland alone	32,520,691
Total yarn spun in England . . .	248,914,531

Being nearly eight times the production of Scotland.

Employment of the said Yarn.

Exported in twist . .	82,457,885	
„ thread . .	1,842,124	
„ goods (manufactured)	97,822,722	
Sent to Scotland and Ireland from England	5,359,000	
Miscellaneous articles, waste, &c.	11,500,000	
Retained for home wear, and stock	49,932,800	
		248,914,531

Exports of Cotton Twist in 1835, by Mr. Reuss.

	lbs.		lbs.
Africa . . .	15,189	Mexico . .	668,886
Belgium . .	14,645,506	Naples and Sicily .	2,246,927
Brazils . .	194,778	New Holland .	4,060
British West Indies	3,459	Prussia . .	10,791
British N. America	153,597	Portugal . .	272,717
Chili and Peru .	7,320	Russia . .	21,478,499
Columbia . .	1,200	Sweden and Norway	925,309
Denmark . .	14,800	Spain . . .	1,788
France . .	75,145	Sardinia, Tuscany, &c. . . .	2,298,541
Gibraltar . .	37,944	Trieste and Austria	1,777,805
Hanover and Hanse Towns . .	29,306,538	Turkey & the Levant	*1,667,441
India and China .	5,305,512	United States of America . .	131,060
Malta and the Ionian Isles . .	417,046		
Mauritius and Java	237,726	Total .	82,457,885

* Egypt, 558,630 of that quantity.

Lace-Thread Price List of T. Houldsworth, Esq., M.P.

No.	Price per lb. s.	d.	No.	Price per lb. s.	d.
80 . .	3	6	170 . .	10	7
90 . .	3	10	180 . .	12	0
100 . .	4	3	190 . .	14	0
110 . .	4	11	200 . .	16	0
120 . .	5	8	210 . .	18	6
130 . .	6	5	220 . .	21	3
140 . .	7	3	230 . .	25	0
150 . .	8	2	240 . .	29	6
160 . .	9	2	250 . .	35	0

The price above No. 250 must be fixed by special agreement. The thread is delivered in Manchester, and is thenceforward at the risk of the purchaser.

Dates and Amounts of Excise Duties laid at different Times, from the earliest Period, on Cotton Goods made in Great Britain. Duties commenced 20th July, 1712.

	Per Yard.
Calicoes printed, stained, painted, or dyed . . .	3*d.* yard wide.
From 2d Aug. 1714—Additional duty of the like amount, total	6*d.* „
„ 17th Aug. 1774—Stuffs wholly made of cotton spun in Great Britain, called "British Manufactory"	3*d.* „

„ 5th April, 1779—5 per cent. additional duty on the former duty.
„ 5th April, 1782—A second 5 per cent. as before.
„ 25th July, 1782—A third 5 per cent. as before.
„ 1st Oct. 1784—Duties on cottons, stuffs, and cotton and linen mixed, bleached or dyed, not being linen gauzes sprigged with cotton, viz., under 3*s.* per yard in value, 1*d.* per yard, and 15 per cent. thereon. At 3*s.* per yard in value, or upwards, 2*d.* per yard, and 15 per cent thereon.
„ 1st Aug. 1785—The above repealed, and new duties, viz.:—

	d.	
Linens printed, painted, &c., of greater value than 1*s.* 4*d.* and not more than 2*s.* 6*d.* .	$1\frac{1}{2}$	per. sq. yd.
Do. 2*s.* 6*d.*	$3\frac{1}{4}\frac{8}{10}$	„
Mixed or cotton stuffs, do. 1*s.* 8*d.*, and not more than 3*s.*	$2\frac{1}{4}\frac{2}{10}$	„
Do. 3*s.*	$4\frac{1}{2}\frac{4}{10}$	„
British muslins, do. 1*s.* 8*d.*, not more than 3*s.*	$2\frac{1}{4}\frac{2}{10}$	„
Do. 3*s.*	$4\frac{1}{2}\frac{4}{10}$	„
„ 10th May, 1787—The whole of the above repealed, and new duties in lieu thereof, viz.:—		
British manufactory and British muslin .	$3\frac{1}{2}$	„
Linens and stuffs	$3\frac{1}{2}$	„

These rates continued until the repeal of the duty, 1st of March, 1831.

Duties on Cotton Wool at different Periods.

COTTON WOOL IMPORTED.

Years.	lbs.	Years.	lbs.
1697 .	1,976,359	1730 .	1,545,472
1701 .	1,985,868	1741 .	1,645,031
1710 .	715,008	1751 .	2,976,610
1720 .	1,972,805	1764 .	3,870,392

Inspector-General's Office, 21st Jan., 1834.

RATES OF DUTY ON COTTON WOOL IMPORTED.

	Previous to 1798 . . .	Free.
1798.	Imported by the E. I. Company	£4 per cent. ad valorem.
	From the British Colonies or Plantations . . .	8*s*. 9*d*. per 100 lbs.
	From Turkey and the United States of America . .	6*s*. 6*d*. „
	From any other place . .	12*s*. 6*d*. „
1801.	. . . . . .	Free.
1802.	Imported by the E. I. Company	£4. 16*s*. per cent. ad val.
	From Turkey and the United States of America . .	7*s*. 10*d*. per 100 lbs.
	From the British Colonies and Plantations . . .	10*s*. 6*d*. „
	From any other place . .	15*s*. „
1803.	From the East Indies, Turkey, the United States of America, and any British Colony or Plantation . . .	16*s*. 8*d*. „
	From any other place . .	£1. 5*s*. „
1805.	E. I. Company, Turkey, United States of America, and any British Colony or Possession	16*s*. 10½*d*. „
	From any other place . .	25*s*. 3¾*d*. „
1809.	All sorts	16*s*. 11*d*. „
1815.	All sorts	8*s*. 7*d*. „
1819.	From any British Colony or Plantation in America, and imported directly from thence	6*s*. 3*d*. „
	Otherwise imported . .	8*s*. 7*d*. „
1820.	Of any British Colony or Plantation in America, and imported directly from thence .	6*s*. 3*d*. „
	Otherwise imported . .	£6. per cent. ad valorem.
1821.	Of any British Colony or Plantation in America, and imported directly from thence .	Free.
	Otherwise imported . .	£6. per cent. ad valorem.
1826.	Of any British Colony or Plantation in America, or of Malta, and imported directly from thence	Free.
	Otherwise imported . .	£6. per cent. ad valorem.

1828.	Imported from any British Possession	4*d.* per cwt.
	From any other place . .	£6. per cent. ad valorem.
1831.	The produce of, and imported from, any British Possession	4*d.* per cwt.
	Of any foreign country; or imported therefrom . .	5*s.* 10*d.* „
1833.	The produce of, and imported from, any British Possession	4*d.* per cwt.
	The produce of any foreign country, or imported therefrom	2*s.* 11*d.* „

Inspector-General's Office, 21st Jan., 1834.
(Signed) W. IRVING.

The following Tables, compiled by Dr. Mitchell from the Reports of the Factory Commissioners, exhibit the rates of wages for cotton-spinning in the two great factory districts of England and Scotland.

TABLES of the Wages and Ages of the Operatives in the Cotton Manufacture.

LANCASHIRE.				
Age.	Males.		Females.	
	Number employed.	Average Weekly Wages.	Number employed.	Average Weekly Wages.
		s. *d.*		*s.* *d.*
Below 11	246	2 3½	155	2 4¾
From 11 to 16	1,169	4 1¾	1,123	4 3
16 — 21	736	10 2½	1,240	7 3½
21 — 26	612	17 2½	780	8 5
26 — 31	355	20 4½	295	8 7¾
31 — 36	215	22 8½	100	8 9½
36 — 41	168	21 7¼	81	9 8¼
41 — 46	98	20 3½	38	9 3½
46 — 51	88	16 7¼	23	8 10
51 — 56	41	16 4	4	8 4½
56 — 61	28	13 6½	3	6 4
61 — 66	8	13 7	1	6 0
66 — 71	4	10 10	1	6 0
71 — 76	1	10 0	—	—
76 — 81	1	8 8	—	—
	3,770		3,844	

GLASGOW.				
Age.	Males.		Females.	
	Number employed.	Average Weekly Wages.	Number employed.	Average Weekly Wages.
		s. d.		s. d.
Below 11	283	1 11¾	256	1 10¼
From 11 to 16	1,519	4 7	2,162	3 8¾
16 — 21	881	9 7	2,452	6 2
21 — 26	541	18 6	1,252	7 2¼
26 — 31	358	19 11¼	674	7 1
31 — 36	331	20 9	255	7 4½
36 — 41	279	19 8½	218	6 7¾
41 — 46	159	19 6	92	6 6
46 — 51	117	19 2	41	6 10
51 — 56	69	17 9¾	18	6 1½
56 — 61	45	16 1¼	16	6 0
61 — 66	17	17 7	7	5 5
66 — 71	15	15 9½	2	4 0
71 — 76	11	10 11	—	—
76 — 81	5	9 6	—	—
81 — 86	0	0 0	—	—
86 — 91	1	8 0	—	—
	4,631		7,445	

Actual Prices paid for Spinning Mules of different Sizes.

A spinner spinning—

				s.	d.
No. 170, on mules of	336 spindles and	under, is paid		2	0 per lb.
Do. do.	348 to 384	do.		1	11½
Do. do.	396	do.		1	10½
Do. do.	600 spindles is paid				
	at Messrs. M'Connell's, Manchester			1	4½
	at Messrs. Houldsworth's,	do.		1	8½
	at Messrs. Carruthers',	do.		1	6½

A spinner spinning—

			s.	d.
No. 200, on mules of	336 spindles and under .	.	3	6
Do. do.	348	do.	3	5
Do. do.	396	do.	3	4
Do. do.	600	do.		
	at Messrs. M'Connell's . .	.	2	5
	at Messrs. Houldsworth's .	.	2	5
	at Messrs. Carruthers' . .	.	2	8¾

Thus the advantages of large mules over small will give a difference of four to five per cent. in cost of production, but of seven to eight in rate of spinners' wages.

It has been stated to be doubtful whether the large mules, employed as above in fine spinning, can ever be applied to coarse spinning, owing to the greater rapidity of the motion in mules for coarse spinning, and the weight of them. An experienced manufacturer resolves this doubt by saying, that, with the knowledge possessed by modern mechanics of diminishing friction, and with the superior accuracy of their work, a spinner can manage two mules of 600 spindles for coarse spinning with as much ease to himself, and with no less, or more rapidity of the machinery, than he did two mules of 300 spindles each ten years ago. "I have not seen mules of 600 spindles for coarse work yet fitted up; but I have myself fitted up a pair of mules for my master, of 512 spindles each, for coarse work, and they answer so well that I see that I could easily and certainly add 100 spindles to them."*

Estimate of cost of a fire-proof mill of 24 windows long (exclusive of engine-house), 9 feet bays, 42 feet wide, and 7 stories high, with a steam-engine of 100-horse power, to turn 24,000 spindles, spinning No. 40; 12,000 throstle spindles, spinning No. 30; with all necessary preparations for the same.

Suppose the mill 75 yards long (including engine-house), 13 yards wide, and 7 stories high, containing 6,825 square yards of flooring, cost about 50*s*. per square yard, and include mill, mill-gearing, steam-pipes, steam-engine boilers, boiler-house, gas-house, gas apparatus, and other appendages to complete the mill; 6,825 yards, at 50*s*., cost . . . £17,062

* Rowbotham in Factory Commission Report, Part I., Bolton, p. 133.

A fire-proof warehouse of 10 windows long, 5 stories high, 30 feet wide, for cotton cellar, waste place, counting-house, twist rooms, reeling rooms, making-up and taking-in rooms, &c., will contain about 1,500 square yards flooring, at 30*s*. £2,250

A mill of the above dimensions will contain, and an engine of the above power will turn, the following spinning machinery and preparation, and will produce weekly the following weight of yarn :—

	lbs.			
12,000 throstle spindles, at 22½ hanks, or three quarters of a pound, per spindle of No. 30.	9,000	at 200 spindles per horse	=	60 horses.
24,000 mule spindles, at 18 hanks, or three quarters of a pound, per spindle of No. 40.	10,800	at 600 spindles per horse	=	40 horses.
	19,800			100

Machinery.

One willow		£ 80
Three scutchers	£ 60	180
Three lap machines	60	180
One hundred cards, forty-inch, and covered with cards	50	5,000
Three card grinding machines	30	90
Twelve drawing frames, four heads each	40	480
Twelve slubbing frames	67	804
Forty-eight fine frames	81	3,888
Twelve thousand throstle spindles, in eighty throstles, of one hundred and fifty each, at 9*s*. per spindle		5,400
Twenty-four thousand mule spindles, in forty pairs of three hundred spindles per mule, at 5*s*. per spindle		6,000
		22,102
Cost of mill		17,062
Cost of warehouse		2,250
		£41,414
Cop and bobbin reels	£300	
Mechanics' shops, lathes, vices, and tools	200	
Counting-house	100	
Cotton and twist warehouses, waste places, &c., fitted up	100	
		700
Carried forward		£42,114

Brought forward . .		£42,114
Cans	300	
Straps	400	
Bobbins for slubbing and jack-frames and mules .	410	
Bobbins for throstles	60	
Doffin tins	100	
Skewers	50	
Skips	100	
Banding, list, buckles, &c.	100	
Roller leather, and rollers covering . . .	250	
Making up presses, counters, weights, and scales .	100	
Horse, cart, gear, stable	150	
		2,020
		44,134
Purchase of land and procuring a supply of water for engine		3,000
Total cost		£47,134

In a mill of the before-mentioned dimensions, and seven stories high, the different stories would probably be occupied as follows:—

One and a half story for 100 cards, of 40 inches, and preparation; say 6 feet per engine.

Half story for scutching, and cleaning, binns, and mixing.

One story for 80 throstles of 150 each, equal to 12,000, at 5½ feet per pair.

Four stories for 10 pairs of mules of 300 spindles per mule in each room, equal to 24,000.

Warehouse.

Cellar for cotton and waste.
Ground floor, counting-house, and twist rooms.
Third story, making-up and store rooms.
Fourth and fifth stories, reelers, &c.

The above estimate is made up by a very competent person engaged in the construction of machinery, and who has a mill of his own. But such estimates generally fall much below the actual outlay. The owners of mills would give their separate valuations at a much higher rate *.

* Holland Hoole, Esq., in Factory Commission Report, Part I., Manchester, p. 96.

The great differences in the average rates of wages paid by different mill-owners in Manchester for spinning the same quality and fineness of yarn with similar mule-jennies is one of the most remarkable, and, at first sight, most puzzling circumstances in the factory system. Thus we find that the average rates of weekly wages, or net earnings, in 69 hours of each individual employed, in the following fine spinning-mills, are as follow:—

Name of Firm.	Fineness of Yarn or Counts spun.	Average Fineness.	Total of Operatives.	Average Earnings in one week of 69 hours, of each individual of all ages.
M Connell & Co. .	100 to 240	170	1,545	131·03 pence.
T. Houldsworth, M.P.	130 to 230	180	1,201	122·72
A. and G. Murray .	90 to 200	145	841	141·96
T. R. and T. Ogden .	150 to 220	176	712	125·
Benjamin Gray . .	100 to 200	130	391	113·5
Benjamin Sandford .	140 to 210	175	382	112·94
Thomas Plant . . .	140 to 210	175	343	112·34
J. and W. Bellhouse	130 to 210	170	211	148·46
S. M. Moore	150 to 210	180	189	129·49
Hugh Shaw and Co.	150 to 210	180	182	111·8
William Carruthers	150 to 210	180	143	146·24

The average net weekly earnings of all the adult mule-spinners, in the coarse and fine mills of Manchester, is 325·64 pence, or fully 27*s*. That of the men spinners alone in the fine mills varies from 30*s*. to 40*s*., which, with the wages of two children as assistants, at an average of 5*s*. each, will make up an excellent income for a working man's family, one very different indeed from the 12*s*. or 14*s*. earned by a like family in the agricultural districts of England.

But the extraordinary phenomenon in the above table is the difference of wages paid in similar mills

of the same town for work of like quality. Thus, in three mills which spin the average count of 180 hanks of yarn in a pound weight, or nearly 90 miles' length out of one pound of cotton, the average wages to the workmen are 122·72 pence, 129·49 pence, and 111·8 pence. The latter two, which differ so much, are moreover of the same extent, or employ nearly the same number of hands.

These differences are well known to the operatives in Manchester from the constant intercourse which subsists between them, and yet they create no jealousies either among them or the masters, because the spinners are paid according to a general table, called the *Manchester List of Prices*, agreed upon and fixed for a certain period, according to the number of spindles in a mule, and the fineness of the yarn.* The more spindles there are in a mule, the more yarn can a spinner turn off, and, though his earnings relatively to each spindle may be less, his weekly wages for like labour on his pair of mules becomes greater, while the cost of spinning to the master is diminished. Thus operative, owner of the mill, the commerce of the country, and mankind at large, all simultaneously profit by this factory progression.

The causes of the above differences are very complex. Some mills, like Mr. Houldsworth's, which, according to the principle of fineness of yarn, ought to pay fully the average wages, pay less in consequence of the number of machines employed in it for doubling the fine yarn into thread for making lace. Now these doubling machines are superintended by young persons, who work, of course, at much lower wages than

* See Philos. of Manufactures, page 319.

skilful adult spinners. Again, factories which have mules containing most spindles employ the largest proportion of juvenile piecers and scavengers, and, of course, pay a less average rate of wages among the whole operatives. Some mills, also, which are filled with modern machinery of the best kind, but not with very large mules, enable the spinner to turn off a proportionably greater quantity of work, and to earn proportionably higher wages,—a result most advantageous to the mill-owner, as it makes his sunk capital so much the more productive. Hence, in these circumstances, the higher average rate of wages he pays, the more prosperous he is. On the contrary, when a manufacturer works his mill with very long mules, such as contain from 800 to 1,000 spindles, he needs fewer spinners at high, and more piecers at low wages, and will therefore pay a lower average rate, which will be in this case the cause and measure of his prosperity. When a long mule is constructed in the best possible manner, a prudent operative may choose to take work on it at a rate per pound of yarn under the *printed list prices*, because he can even then earn a very large weekly sum. Under such a variety of circumstances the average rate of wages paid by the mill-owner may undergo considerable variation, without any person in the trade having just reason to blame either master or servant.

The following is the result of an average of several men's work at different periods. There are 111 spinners at present employed in the mill, each earning, on an average per week, 33*s*. 3*d*. In the same factory 917 persons are employed in card-rooms, doubling, reeling, and piecing; *their* net earnings average 7*s*. 1*d*. per week.

Particulars of Fine Cotton-Spinners' Wages at different Periods, spinning No. 180 and No. 200; from the Wages-book of Thomas Houldsworth, Esq., M.P., Manchester.

Years.	Work turned off by one Spinner per week.		Wages per week.			Hours of work per week.	Prices from Greenwich Hospital Records.		Quantities which a week's net earnings would purch.	
	lbs.	Nos.	Gross.	Piecers.	Net.		Flour per sack.*	Flesh per lb.	lbs. Flour	lbs. Flesh.
			s. d.	s. d.	s. d.		s. d.	d. d.		
1804	12	180	60 0	27 6	32 6	74 sup.	83 0	6 to 7	117	62½
,,	9	200	67 6	31 0	36 6	74	83 0	6 to 7	124	73
1814	18	180	72 0	27 6	44 6	74	70 6	8	175	67
,,	13½	200	90 0	30 0	60 0	74	70 6	8	239	90
1833	22½	180	54 8	21 0	33 8	69	45 0	6	210	67
,,	19	200	65 3	22 6	42 9	68	45 0	6	267	85

* The sack of flour is taken at 280 lbs.

Rates of Wages per Week at the different Periods in the same Mill.

	1806.	1811.	1815.	1818.	1824.	1833.
Card-room.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Males . .	15 0	15 0	15 6	15 0	15 0	15 0
,,	17 0	17 0	18 6	18 0	17 9	17 9
,,	35 0	35 0	40 0	40 0	40 0	30 0
Females .	9 0	9 0	10 0	9 0	9 0	9 0
Reelers ,,	19 to 30	15 0	15 0	15 0	15 0	12 0
Doublers ,,	12 0	10 6	10 6	9 6	9 6	8 6

Piecers' wages, with the exception of those of big piecers, who constitute one-third of the whole, have not varied sixpence per week within the last twenty years. Mechanics' wages, such as blacksmiths, turners, filers, machine-makers, and fitters-up, are now from 27*s*. to 31*s*. per week. Within the last twenty years they have been as high as from 28*s*. to 35*s*.;

but then they worked from half an hour to an hour per day longer.

Although a great deal more work is now done in certain factories than formerly, it is done with fewer hands; and, though a factory be increased in extent, the money wages paid in it may be the same as before. Mr. K. Finlay states that, about the beginning of the present century, the profit upon a piece of cotton goods to the manufacturer was as much as the price of the goods altogether is at present.

It will be seen from the authentic Table of the Wages earned in Cotton Factories (*see* Appendix to Vol. I., pages 347, 348, and 349), that there never was a time when the prudent operative was better off than at present, considering the quality and price of provisions, the extreme cheapness of clothing, and the number of charitable institutions that minister to his wants, and those of his children. And, notwithstanding the clamour and lamentation about the moral and physical evils concomitant on our manufacturing aggrandizement, it is certain that the condition of the work-people thirty-five years ago was greatly inferior in most respects to the present. "At that time," says a very competent judge, "the spinners were not held to any regular hours of work; they frequently spent two or three days in the week in idleness and drinking, letting the children in their service linger for them at the public houses till they were disposed to go to their work; to which, when they did return, they would sometimes work desperately, night and day, to clear off their tavern score, and get more money to spend in dissipation." Such practices are now unknown, and would, in fact, be no longer endured by any manufacturer.

Number of Hands, and their Occupation, in a Cotton Spinning Mill for Fine Numbers, with 52 Pairs of Mules.

	Men.	Women.	Boys.	Girls.
Cash-keeper . . .	1			
Clerks or book-keepers .	2			
Cotton taker-in, and assistant .	2			
Two head carders, one under do.	3			
Grinders . . .	4			
Cylinder-strippers . .	2			
Top-card-strippers . .	12			
Brushers . . .	3			
Card-tenters . . .	..	..	13	
Spreaders . . .	..	..	14	
Drawing-frame-tenters . .	..	28		
Jack-tenters . . .	..	13		
Stretchers 14, back-tenters 14 .	..	14	..	14
Roving-sorters . . .	..	3		
Two roller-coverers, 1 ledge-tenter	3			
Mechanics . . .	6			
Engineers . . .	2			
Batters and pickers, about 90, all grown-up women .	..	90		
Spinners . . .	103			
Piecers . . .	..	..	306	97
Wrapper . . .	..	1		
Reelers, about . . .	..	15		
Cop-rackers . . .	..	..	3	
Yarn-examiner . . .	1			
Overlookers . . .	2			
Watchman . . .	1			
	147	164	336	111
	336			164
Males .	483	Fem	ales .	275
758 Hands altogether.				

NOTE A,

TO PAGE 391, VOL. II.

Having transmitted to my kind friends, Messrs. Boden and Morley, of Derby, the proof sheets of my chapter on bobbin-net, I received the following communication in return, which, coming too late to enable me to correct the press in the body of the book, is here presented *verbatim* to my readers. Certain of the errors which I have inadvertently committed were occasioned by my following a great London authority upon this intricate subject. I have much pleasure in publishing these friendly animadversions, not only on account of their intrinsic truth and value, but as demonstrating the liberal spirit and intelligence of English manufacturers.

"You say (page 339) 'The first machine for making lace from a stocking frame was constructed in 1777, which has been claimed both by Mr. Frost and by Holmes, a poor workman of Nottingham. This was, ere long, superseded by the point-net machine, the ingenious invention of Mr. John Lindley, sen., &c.'* As this account refers to circumstances with which I am not fully acquainted, I am unable to give you a complete and correct history of them; but I am persuaded there is some inaccuracy in your account, which I will endeavour to point out by giving you my ideas of the circumstances, which I received from persons in the trade much older than myself. Various kinds of network were made from the stocking frame prior to the time you name, none of which, however, much resembled lace-net until the invention of a fabric called square net, for which Mr. Robert Frost had a patent. This was soon

* This account was copied, I believe, from Glover's History of Derbyshire.

superseded by the invention of point-net, the most perfect description of net-work ever produced from the stocking frame. This is generally supposed to have been an invention of a poor man of the name of Holmes. This invention, however, only went to show, that by a new and particular mode of arrangement of the loop upon the stocking-frame a beautiful kind of net-work could be made, but how this was to be accomplished with facility was still wanting. This was effected by the addition or appendage to the stocking frame called the point-net machine, and which appears to have been the result of the united ingenuity of several individuals. Two persons of the names of Flint and Morris are supposed to have assisted, but what share they had in it is difficult to determine, but a person of the name of Taylor, a maker of stocking frames, had a patent for it. It, therefore, could not be the sole invention of Mr. John Lindley, as your account implies.

"Page 350. You enumerate twelve different systems of bobbin-net machinery; this is incorrect; there are only six that deserve that distinction. 1st. Heathcoat's patent machine. 2d. Brown's traverse warp. 3d. Morley's straight bolt. 4th. Clarke's pusher principle, single tier. 5th. Lever's machine, single tier. 6th. Morley's circular bolt. All the others are mere variations in the construction of some of their parts. For instance, 'the improved double tier, or Brailey's,' and 'the Old Loughborough improved, with pumping tackle,' are slight variations of Heathcoat's patent machine, and, like it, are now laid aside. 'The single tier, on Stevenson's principle,' is the lever machine lying horizontally, as you have before described, page 344. 'The circular comb, or Hervey's,' is nothing more than a slight difference in the construction of the bolt on which the carriage rides in the circular bolt machine. 'The improved levers' have nothing new in their system or principle. 'The traverse warp rotatory,

or Lindley and Lacey's,' may have *some* claim to distinction from the rest, as it is a combination of two of the different systems or principles: viz., 'Brown's traverse warp,' and 'Lever's machine, single tier;' but is now entirely out of use.

"Page 351. You will perceive you have contradicted what has been said in page 345, 'Mr. Morley's circular bolt is the only machine which has been found capable of working successfully by mechanical power,' which is quite correct.

"Page 367. Beginning with 'the number of movements, &c.,' substitute the following; viz.

"The number of movements which are required to form a row of meshes in the double-tier machine are six; that is, the whole of the carriages pass from one bolt bar to the other six times, during which passages the different divisions of bobbin and warp threads change their relative positions twelve times, as is hereafter explained.

"Page 371. In the paragraph beginning 'The carriage G, &c.,' substitute this for the last sentence. The carriages are driven by the pressure of the bars, *l*, *l*, placed above the bolt or comb until the catches or points *i*, *i'*, are taken hold of by the locker plates *n*, *n'*, and carried forward.

"I think the sentence page 367 should be inserted page 374, just preceding the one commencing with 'To give now an idea, &c.'

"For page 377, beginning 'However, before the 2d line, &c.,' down to 'Fig. 5, at the following operation,' page 378, substitute the following: While No. 10 is performing, and before the carriages G are again pushed to the bolt *k*, the beam H' makes another shift or traverse back to its former position; this places the line G one step to the right of its former position, whilst the line G' reoccupies its first position. While No. 11 is performing, the beam H' shifts one step to the left, as was performed in No. 9, which places

the line G′ one step to the left of what they before occupied, and two steps to the left of the position which the line G now occupies. Whilst No. 12 is performing, the beam H′ returns to its original position, and remains until the same is again required. This interchange or traversing of the carriages with their bobbins, which is the most difficult thing to explain, and a most important principle in the lace machine, will be best understood by a careful attention to the following diagram and explanation. Where the sign | represents the bolts, the sign the back line of carriages, and the sign represents the front line of carriages; H is the front beam or bolt-bar, and H′ the back beam or bolt-bar. It must be borne in mind that the front bolt-bar H remains always fixed and stationary, and that there must be an odd carriage.

"No. 1 represents the carriages in the front bar, the odd carriage being on the left. The back line of carriages are first moved on to the back bar H′, the odd carriage, as seen in No. 1, having been left behind, there being no carriage opposite to it to drive it over; the carriages then stand as in No. 2; the bar H′ then shifts to the left, as shown in No. 3; the front carriages now go over into the back bolt-bar, which is represented by No. 4; the bar H′ now shifts to the right, No. 5; the front carriages are then driven over to the front bar, which leaves the odd carriage on the back bar on the right, for the same reason as before described, and the carriages stand as in No. 6. The bar H′ now shifts to the left, and the carriages stand as in No. 7,—(observe the odd carriage is now on the back bar to the left.) The back carriages now come over to the front bar, and stand as in No. 8. The back bolt-bar H′ shifts to the right as No. 9, which completes the traverse. The whole of the bobbins and carriages have now changed their position, as will be seen by comparing No. 9 with No. 1. The

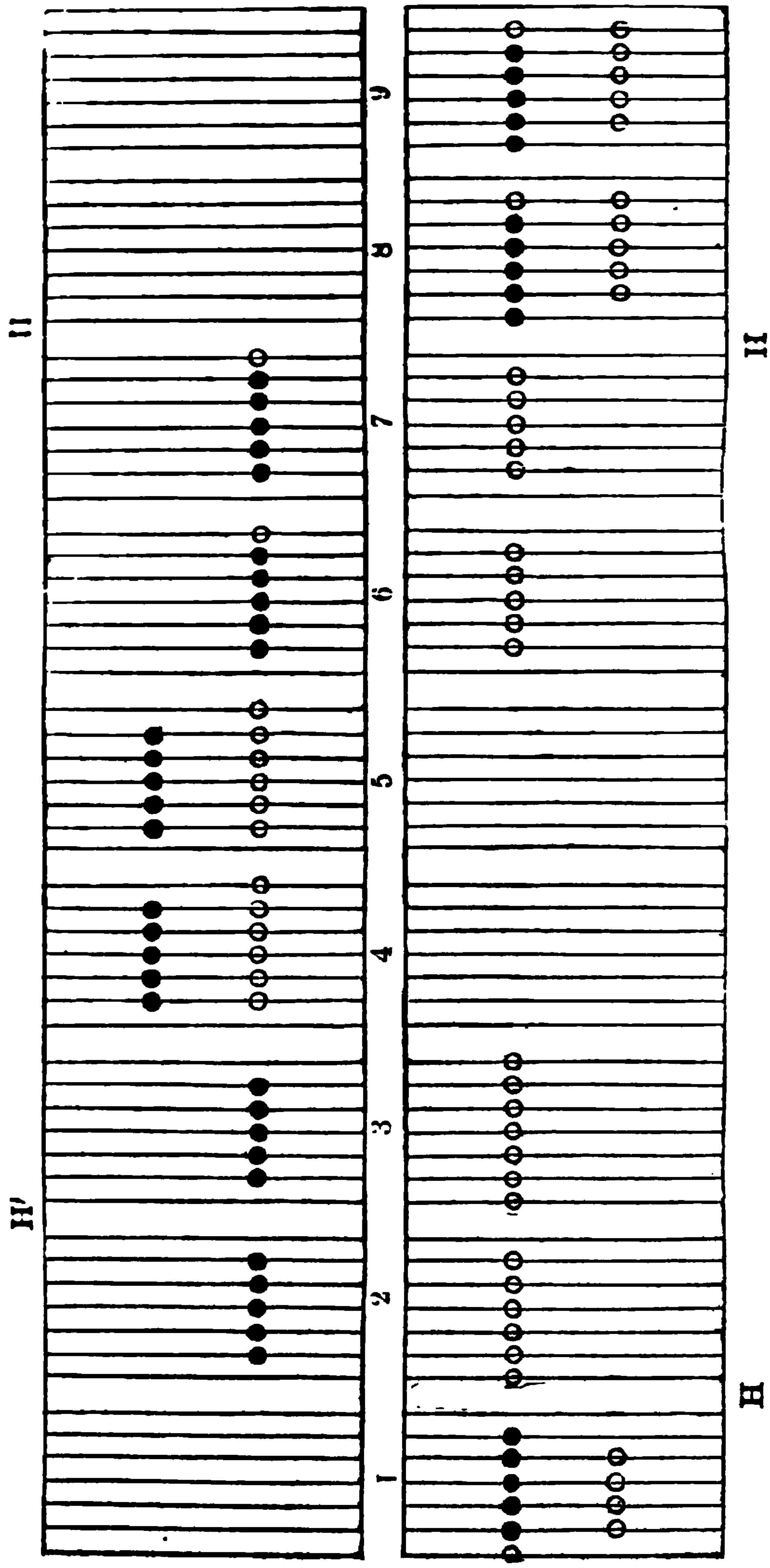


Fig. 132.—Scheme of Bobbin Movements in making a Mesh of Lace.

odd carriage in No. 1 has advanced one step to the right, and become one of the front line; one of the back line has advanced one step to the left, and has become the odd carriage; and one of the front ones has gone over to the back line on the right. The bobbins and carriages throughout the whole width of the machine have thus crossed each other's course, and completed the mesh of net.

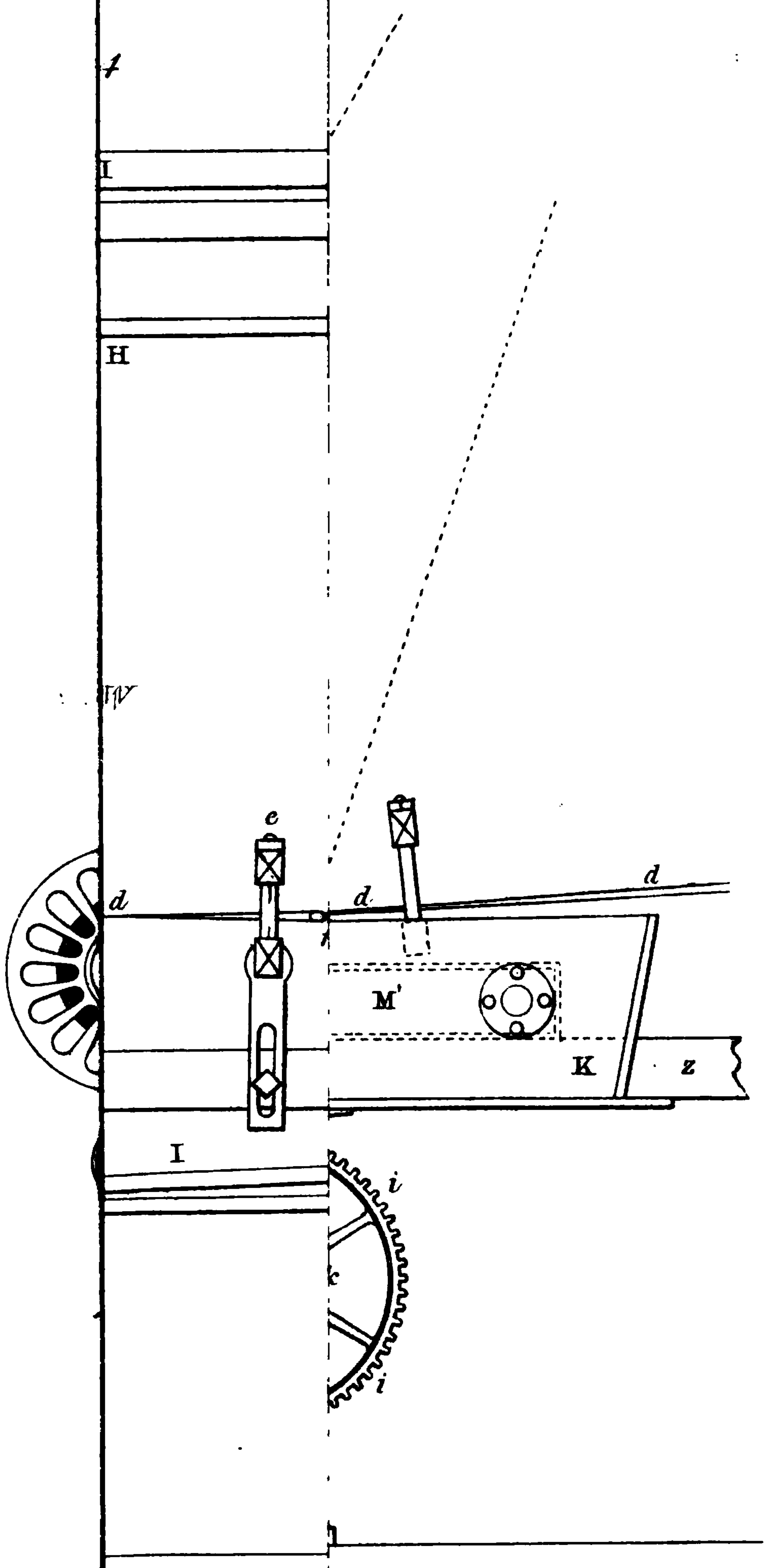
"Page 382, after the words 'against one of the rods d',' substitute this, 'and moves one of the bars L, L′, with its points out of the lace before it descends.'

"Page 389. 'A rack is a certain length of work counted perpendicularly, and contains 240 meshes or holes. Well-made lace has the meshes a little elongated in the direction of the selvage.' The other part of this paragraph I think better omitted."

THE END.

London: Printed by William Clowes and Sons, Stamford-street.

PLATE 8.

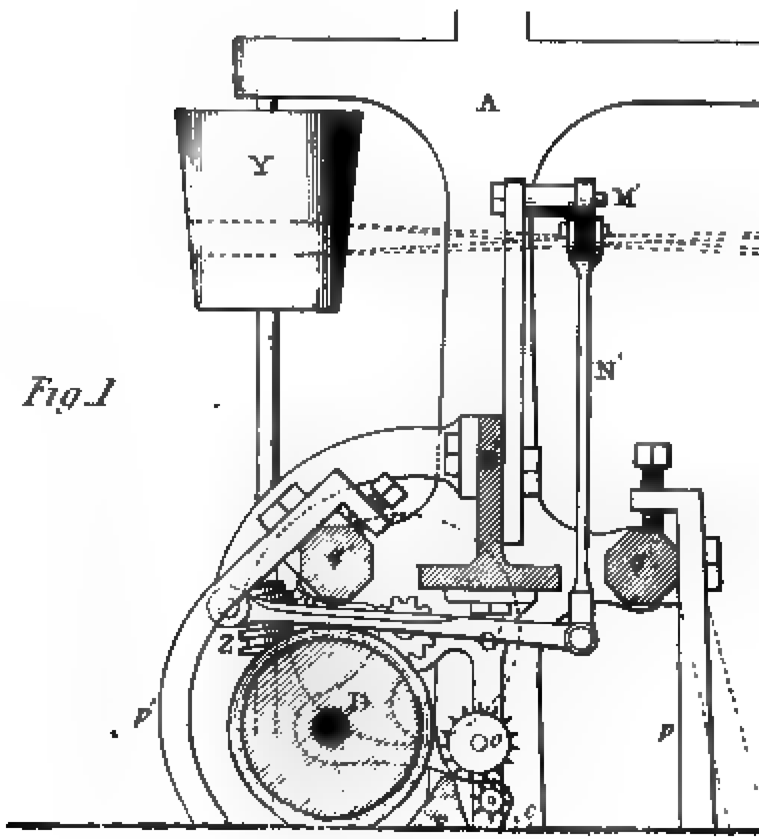


Machine

J. W. Lowry sculp.

Street, May 1. 1836.

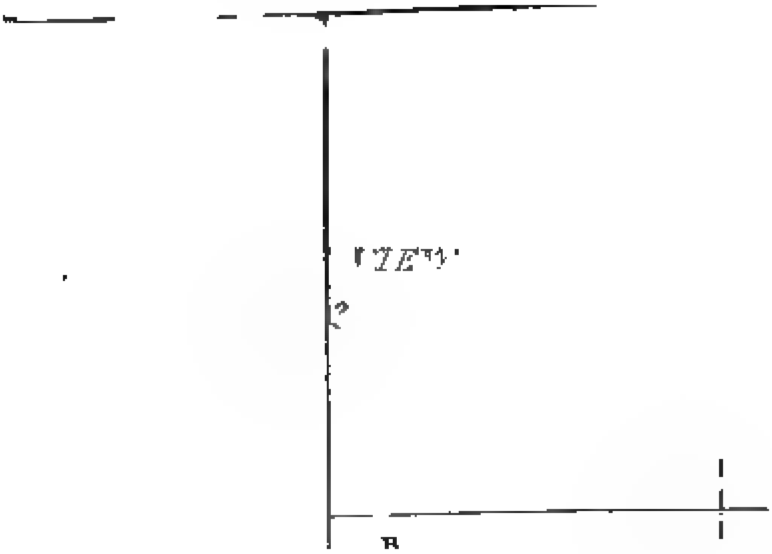
Fig 1



SECTION.

Fig 5

PLATE 10.



ENG.

J. W. Lowry sculp